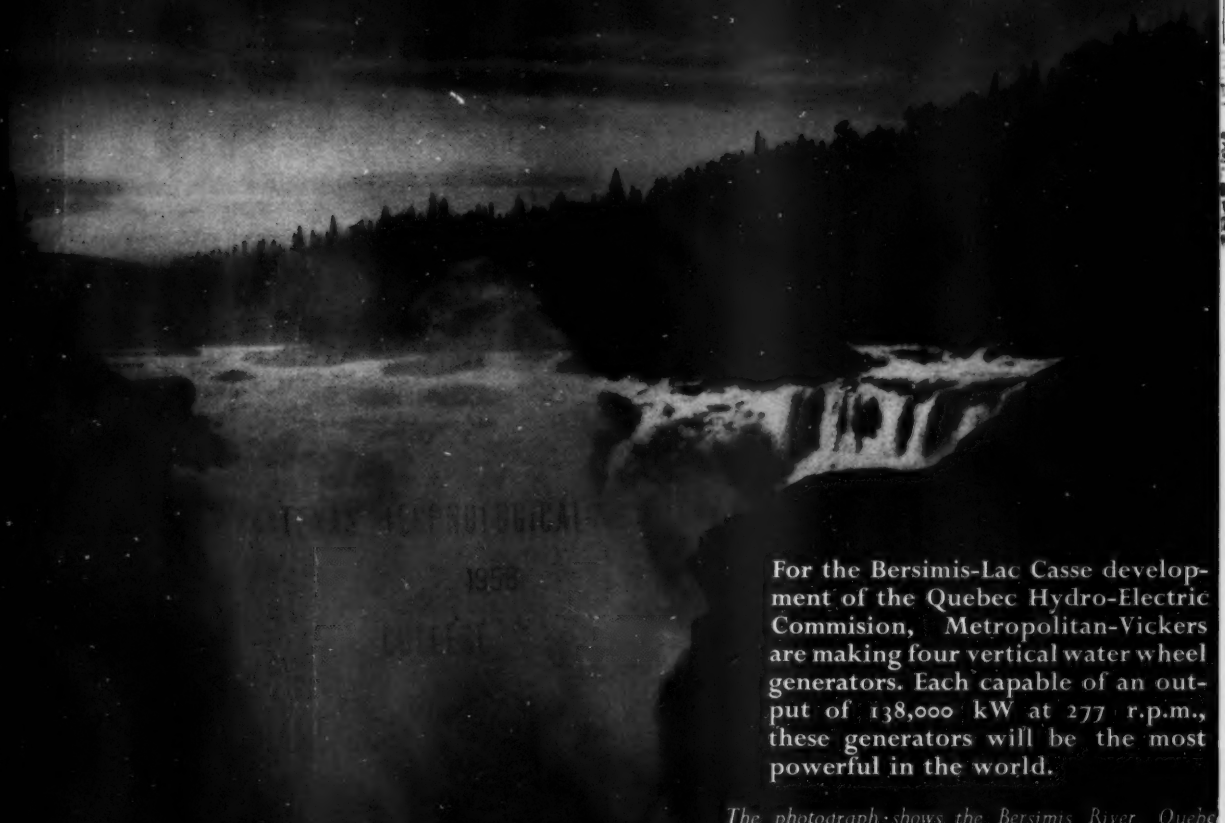
Water Power

INTERNATIONAL DEVELOPMENT OF HYDRO-ELECTRIC POWER

NOVEMBER 1956



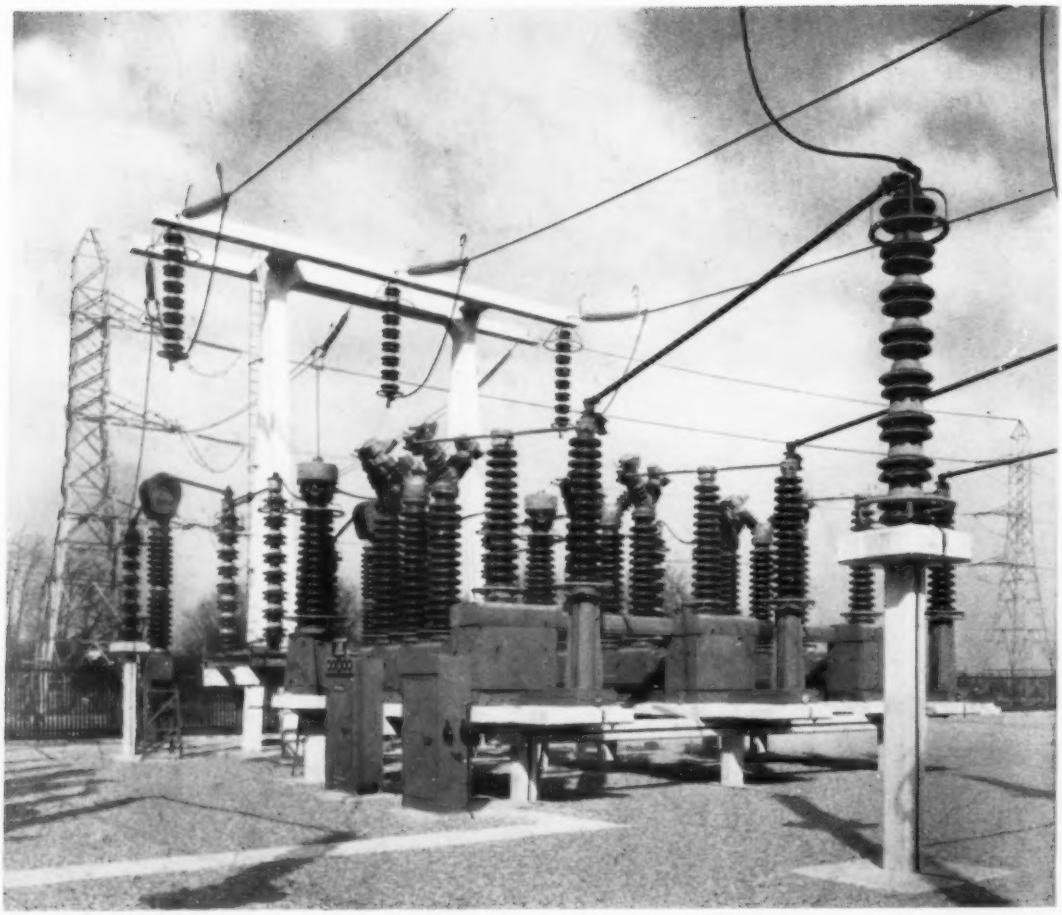
For the Bersimis-Lac Casse development of the Quebec Hydro-Electric Commision, Metropolitan-Vickers are making four vertical water wheel generators. Each capable of an output of 138,000 kW at 277 r.p.m., these generators will be the most powerful in the world.

The photograph shows the Bersimis River, Quebec

METROPOLITAN-VICKERS
ELECTRICAL CO LTD · TRAFFORD PARK · MANCHESTER, 17

Member of the A.E.I. group of companies.

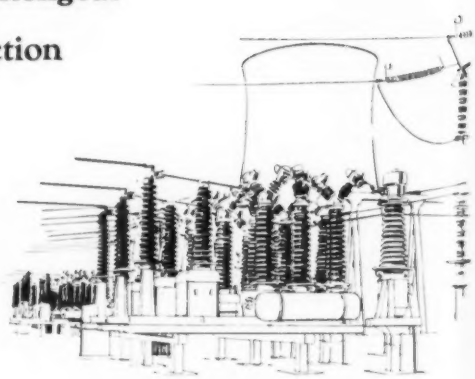
C/A401



Photograph by courtesy of the C.E.A., East Midlands Division

Consulting Engineers : Merz and McLellan

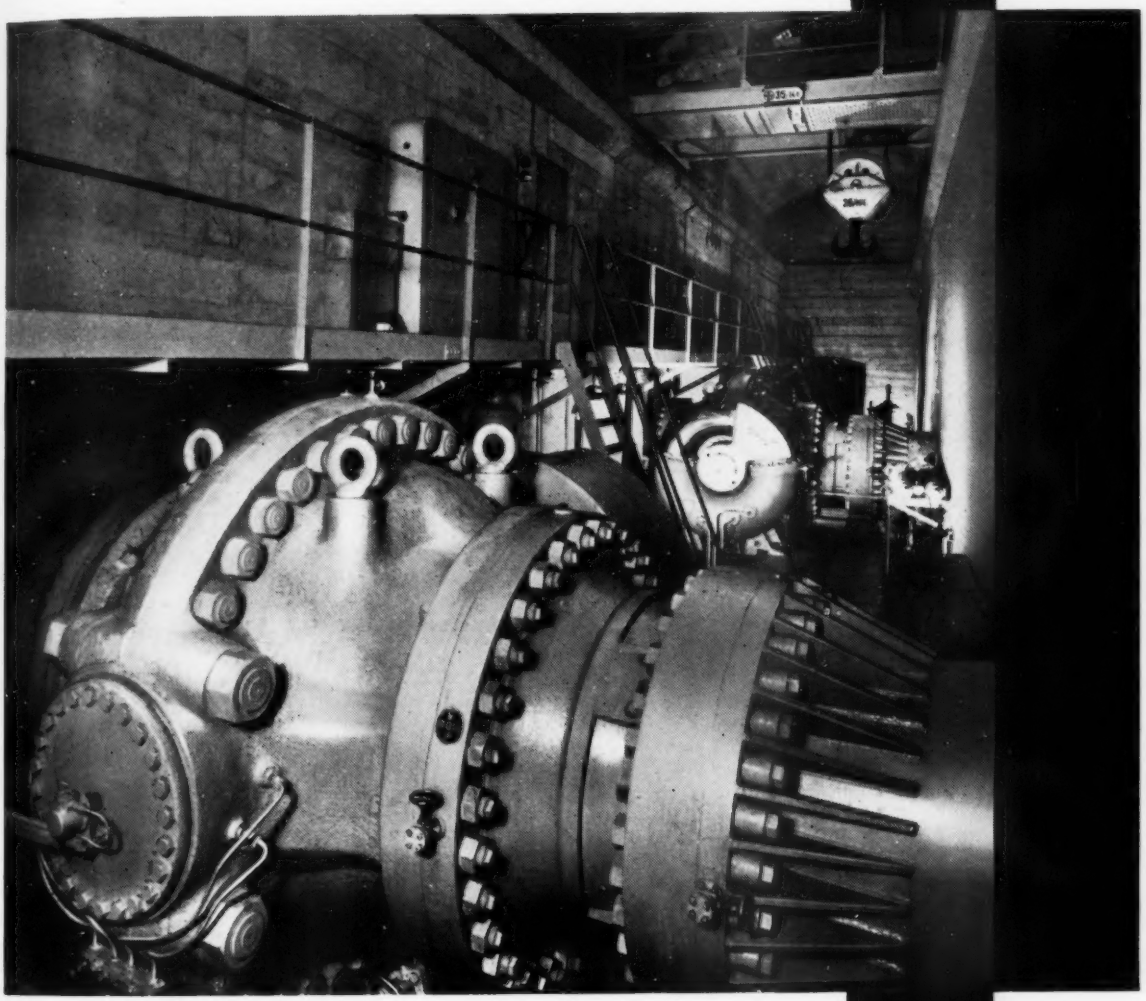
At Drakelow, the largest 275-kV installation in Great Britain, Reyrolle air-blast switchgear is used with mono-bias busbar-protection



Reyrolle

A. REYROLLE & COMPANY LIMITED HEBBURN, COUNTY DURHAM, ENGLAND

Equipment for Hydro-Electric Power Stations



Valve chamber with rotary slide sphériques valves as turbine shut-off device in a swiss power station

DE ROLL

Louis de Roll, Ironworks Ltd.,
Works at Gerlafingen, Klus,
Choindez, Rondez,
Olten, Berne (Switzerland)

Complete barrage installations; gates and hoisting equipment, gantry- and overhead travelling cranes, trash screen cleaning machinery; sluice gates; control valves for high pressure conduits; automatic safety organs for pipe lines; discharge regulating valves, rotary valves with rotary-piston servomotors, needle valves, butterfly valves, high pressure fittings, piping systems for oil and cooling water plant; funicular and aerial cableways for passenger and goods transport; building machinery for dam-building work.

76

You need not move a waterfall to bring its power home

Most of the big hits in technical development have their origin in the simple little question: "Isn't there a better way . . .?" So when confronted with the immense force of the waterfalls, power engineers hit upon to harness the energy and transport it to consumers far away. However, the longer the distance and the larger the quantity of power, the more severe will be the technical and economic demands placed on the means of transmission. High-skilled technical craftsmanship and long experience are indispensable in this field, and ASEA is known for having both of these assets.

In ASEA's home country, Sweden, the projects of increasing the transmission voltage on a.c. systems as well as high-voltage d.c. systems — two methods on which research all over the world has been conducted for a long time — have advanced from plans to reality.

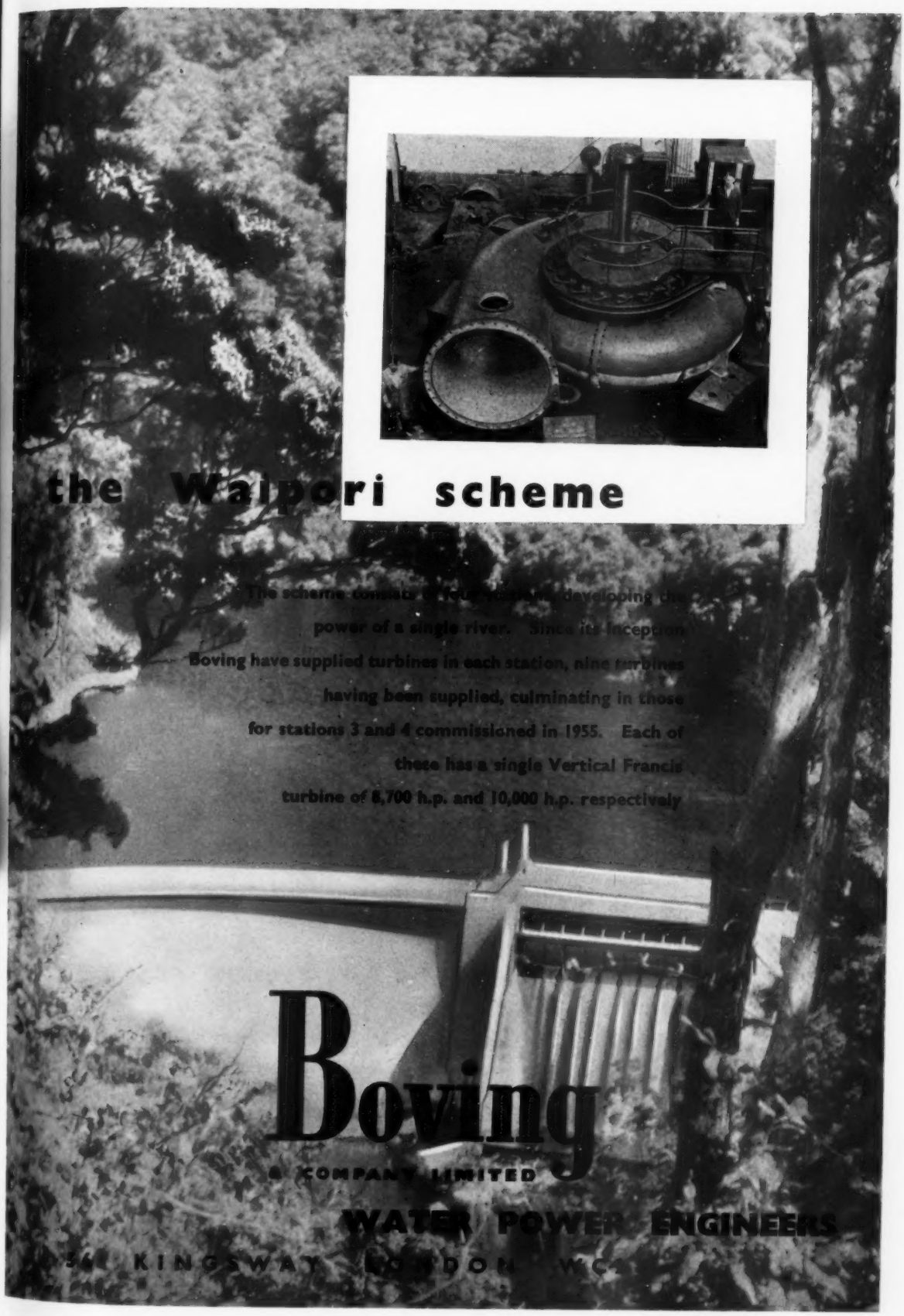
Since 1952 a 400,000 volt a.c. transmission system has been in operation, the highest voltage used previously being 275,000 volt. In 1954 a 100,000 volt d.c. system was commissioned. Incidentally these two projects included the world's longest power line and the world's longest and heaviest submarine power cable.

ASEA has designed and supplied practically all the electrical equipment for these systems. ASEA has also, in collaboration with the Swedish State Power Board, carried out the research work on which the systems are based.

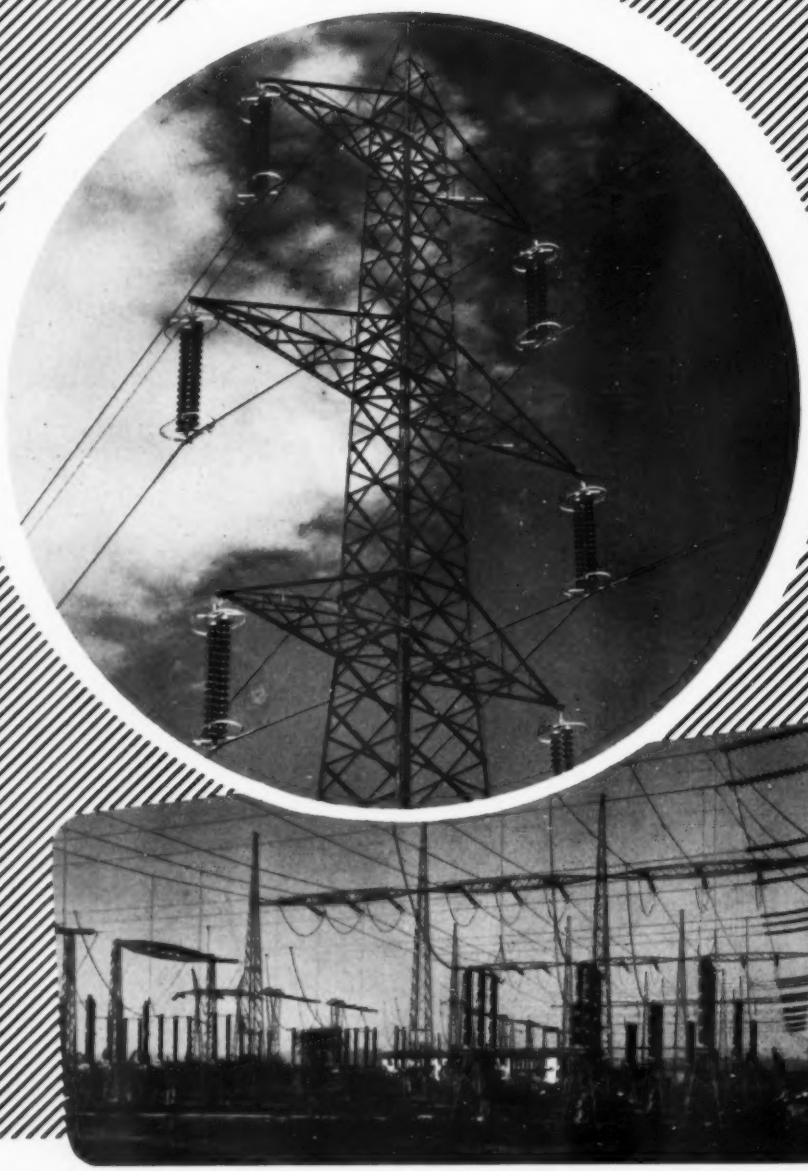
So if transmission is your problem, transmit your worries to ASEA just to get things settled "the better way"!

[redacted]

Västerås, Sweden


the Walpori scheme
power of a single river. Since its inception
Boving have supplied turbines in each station, nine turbines
having been supplied, culminating in those
for stations 3 and 4 commissioned in 1955. Each of
these has a single Vertical Francis
turbine of 8,700 h.p. and 10,000 h.p. respectively
Boving
& COMPANY LIMITED
WATER POWER ENGINEERS

SALVI



3-230 kV Villa Valle-Cornegliano 4 Twin S.C.A. Conductor Transmission Line (Societa TERNI-Rome)

For 30 years Messrs. A. Salvi and Company, Milano, Italy, have specialized in the design and manufacture of complete equipment for Overhead Transmission Lines, including Compression Dead End Assemblies and Joints.
The Works of the Salvi Company are engaged exclusively in the production of high grade fittings for High Voltage Transmission Systems, up to and including voltages of 220/380 KV, and for all sizes of Copper, A.C.S.R. and Aluminium Alloy Conductors.

SOLE REPRESENTATIVES IN THE UNITED KINGDOM AND THROUGHOUT ALL DOMINION COUNTRIES (EXCEPT AUSTRALIA AND NEW ZEALAND) AND BRITISH COLONIES AND PROTECTORATES

THE ENGLISH SALVI COMPANY LTD., 11 Kensington Church St., London, W.8

Telephones: WESTern 8857 and 4412 Cables: ENSALVICO LONDON

For faster drilling,

longer life...

You can't beat the Silver Three. It will out-drill and out-last any other machine of its weight and most heavier ones. And there are figures to prove it. It's designed specifically for use with the work-saving Airleg — and you won't find a better combination anywhere.

BORE:	3" (76 mm.)
STROKE:	1 15/16" (49 mm.)
WEIGHT DRY:	47 lb. (21 kg.)
WEIGHT WET:	49 lb. (22 kg.)

... the record-breaking Silver Three

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Telephone: Camborne 2275 (10 lines)
Telegrams: Airdrill, Camborne
London Office: 44 Brook St., W.1. Hyde Park 9444

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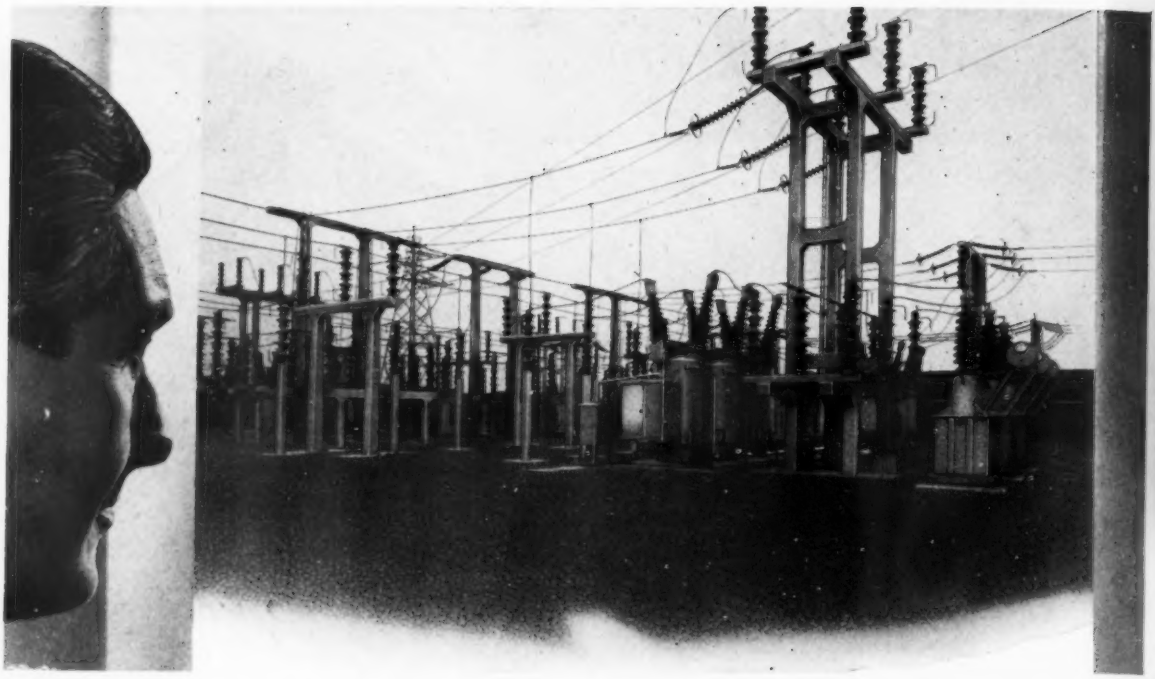


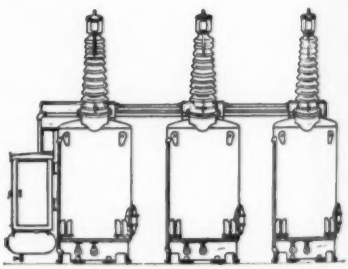
OUTDOOR DEVELOPMENT — and 'F.P.' Switchgear

The onerous conditions—principally climatic—under which outdoor switching stations must operate demand a high degree of specialised knowledge of their construction.

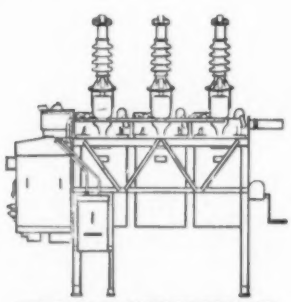
"FERGUSON PAILIN" switchgear is built on the solid foundation of good design and workmanship, with the object of providing, as near as is humanly possible, trouble-free service for a long period of years.

Good examples of oil circuit-breakers from this range are types RPO31 (single tank) and ROP32 (single tank) both for 22/33 kV service; type ROP54 (single tank) for 66 kV service, and type XOPR54 (triple-tank/bulk oil) for 132 kV systems; further details of these and other breakers will gladly be supplied on request.

Space factors and other individual site requirements are carefully considered and catered for by our engineers. "FERGUSON PAILIN" outdoor switchgear may be specified with the utmost confidence, for both materials and assembly are subject to rigid tests and careful scrutiny throughout manufacture.

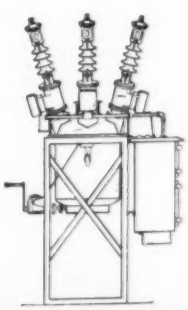


XOPR60 OIL CIRCUIT BREAKER



TTPO24 OIL CIRCUIT-BREAKER

'FERGUSON PAILIN' outdoor switchgear is manufactured for service at ratings of from 22kV to 275 kV.



ROP32 OIL CIRCUIT-BREAKER

Ferguson Pailin LIMITED — *for Switchgear*

Member of the A.E.I. Group of Companies

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Lifting pontoon for 1700 t.
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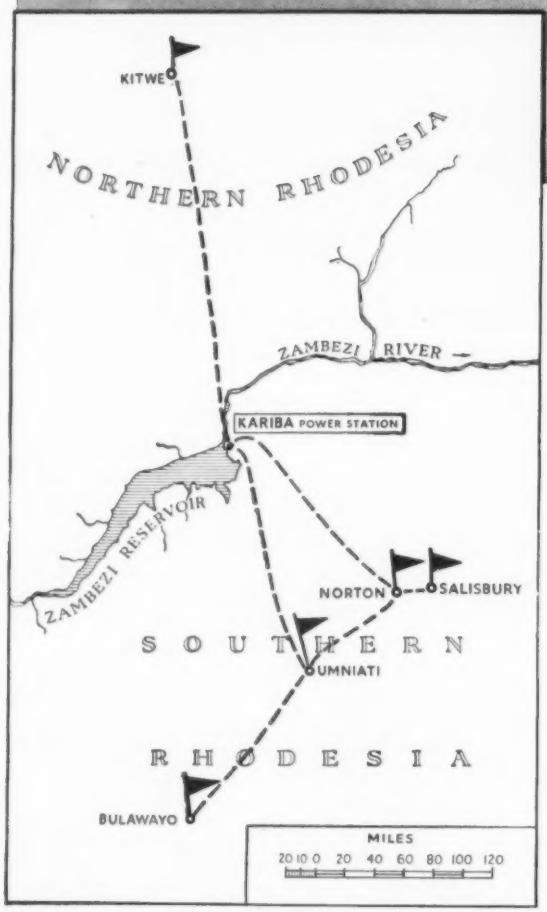
Immerging floating dock

FRIED. KRUPP MASCHINEN- UND STAHLBAU RHEINHAUSEN

THE FIRST 330,000 Volts 3-phase TRANSFORMERS ordered in the UNITED KINGDOM



The transformers will be installed at these sites.

FERRANTI TRANSFORMERS for KARIBA

The contract awarded to Ferranti Ltd. by the Central African Federation Power Board for the great Kariba Hydro-Electric Scheme on the Zambesi River is valued at £1,241,100 and covers two 120 MVA 330/234 kV 3-phase auto transformers with separate boosters; eight 60 MVA 330/88 kV 3-phase double-wound transformers; and two 60 MVA 330/33 kV 3-phase double-wound transformers. All the transformers will be provided with fully automatic on-load tap changing gear.

It will be recalled that in December 1955, Ferranti Ltd. were awarded a contract for the Dalles Dam, Columbia River, U.S.A. which at the time was the largest overseas transformer contract to be placed with a British manufacturer. The Kariba contract is larger than the American contract and emphasises the world-wide confidence in Ferranti Ltd. as builders of fine transformers.

FERRANTI

FERRANTI LTD • HOLLINWOOD • LANCS

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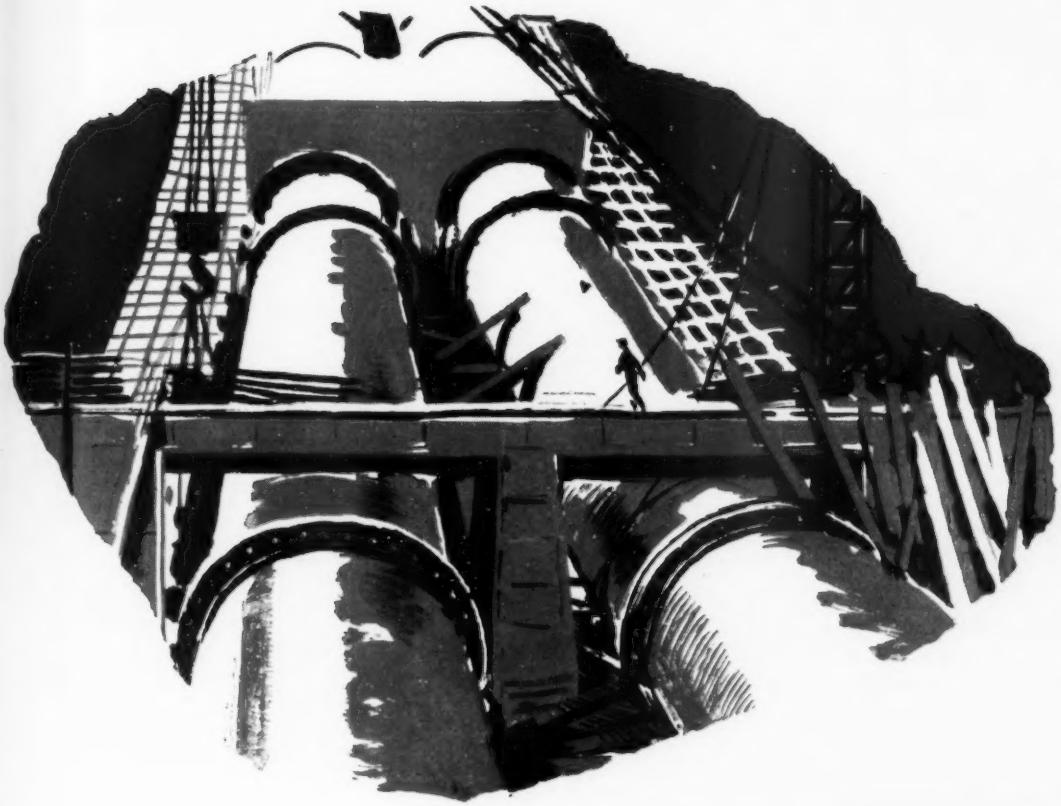
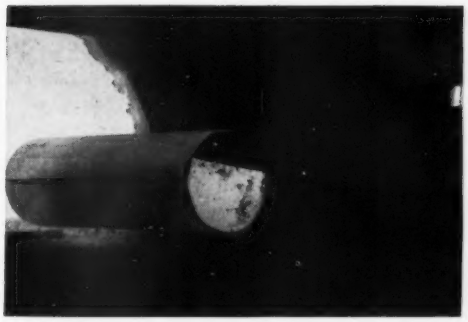


FRIEND OR FOE –

. . . water may be both at once. This much is sure: Man can have no more faithful, no mightier ally than the regimented water in turbine penstocks. It gives us irresistible power, instantly, anywhere. It means concentrated force and unlimited reserves. Mannesmann, the first name in tubes, makes penstocks whose thin walls defy enormous stresses. Mannesmann penstocks set the standard for dependability and economy.



MANNESMANN-EXPORT DÜSSELDORF

REPRESENTATIVES ALL OVER THE WORLD

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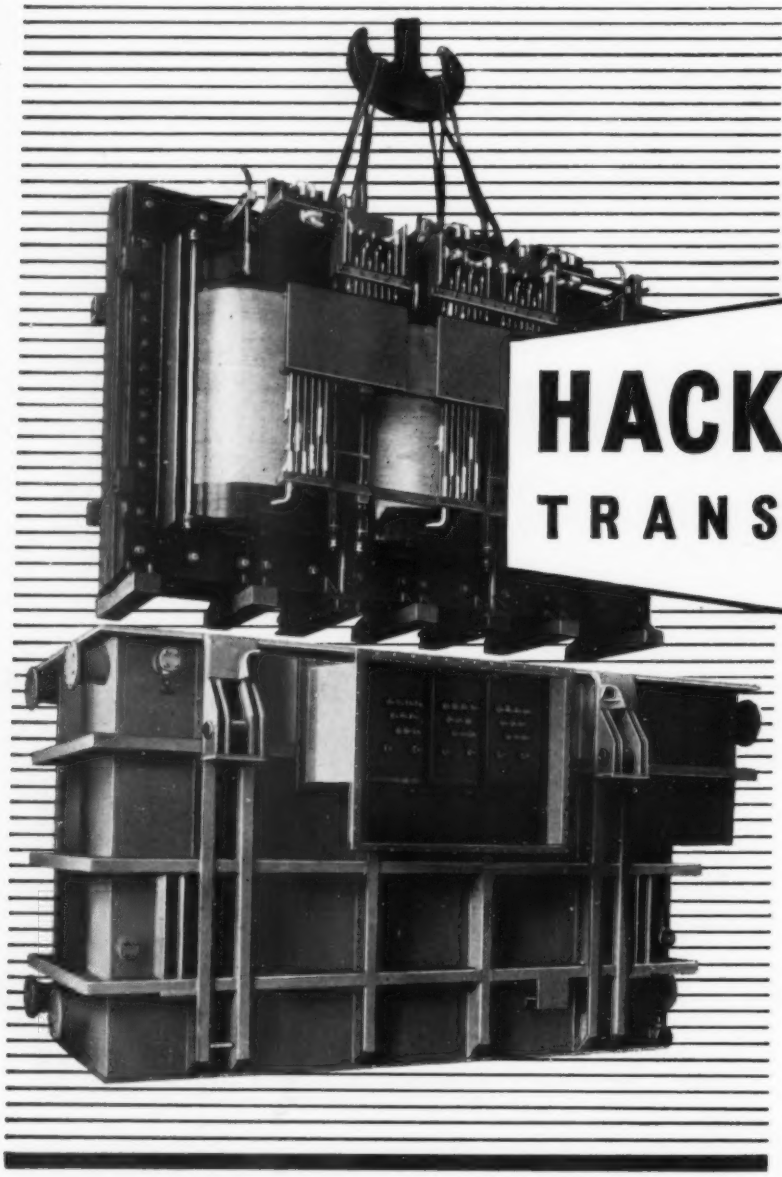

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TRANSFORMERS

Typical 45 MVA Hackbridge transformer 66/33 kV. type ON/OFB, for British Railways.

✻ *There are 22 million kVA of Hackbridge Transformers in World-wide service*

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Steel constructions for weirs and sluices of every description, including the required auxiliary equipment, and mechanical and hydraulic drives for same.
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Severely damaged by war and erosion, South Korea's Hwachon Dam has been a potential threat to the safety of people and property in the Han River Basin and the capital city of Seoul.

IN KOREA— REBUILDING STARTS WITH *ENGINEERING...*

Rehabilitation of this large concrete structure is now in progress under the supervision of International Engineering. Result—life and property will again be secure . . . an important source of power for industrial rehabilitation added, the country's entire economy strengthened.

Engineering projects of unusual scope and complexity are a specialty of International Engineering, a company whose experience record since the end of World War II includes the engineering of more than 20 large-scale dams and power projects throughout the free world. Their engineering services—from survey to supervision of construction—are available to governments and private enterprise world-wide.

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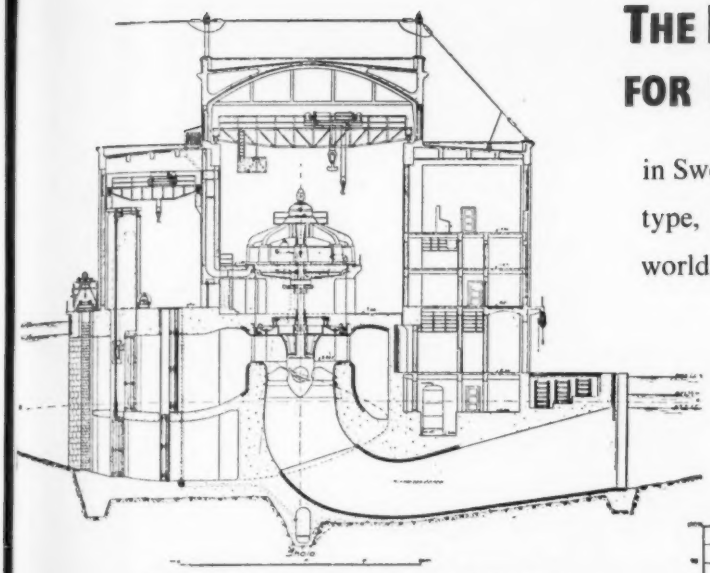
THE KMW KAPLAN TURBINE FOR LILLA EDET POWER STATION

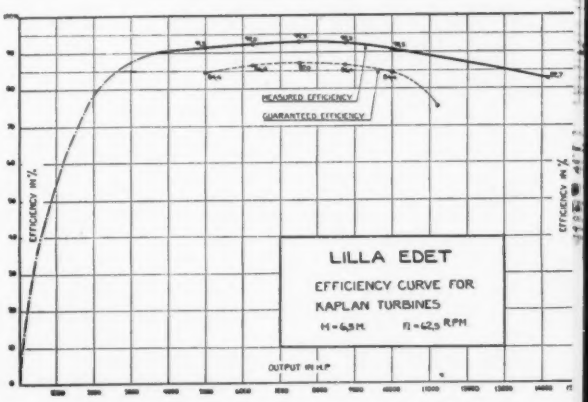
in Sweden opened up the market for this turbine type, not only in Sweden but throughout the world.

KMW



THE SWEDISH STATE POWER STATION AT LILLA EDET

KMW undertook the building of Kaplan turbines 35 years ago, and in 1921 we proposed a turbine of this type with a runner dia. of 5.8 m. for the Lilla Edet Power Station, belonging to the Swedish State. Swedish State Power Board were far-sighted enough to order this turbine the following year. It was started up and became a complete success. Efficiencies above 90% were obtained from 3,500 HP to 10,200 HP with fully automatic regulation of both runner blades and guide vanes and no oil leakage and no difficulties in regulation and operation were experienced.



LILLA EDET. EFFICIENCY CURVE FOR KAPLAN TURBINES.

Since that time KMW have delivered about 280 units with a total output of 4.2 Million HP, this output being greater than that obtained by any other turbine manufacturer.

Among the largest KMW turbines of Kaplan type can be mentioned:

Year	Customer	Plant	Country	Head		Output	Speed
				Met.	Feet	B.H.P.	r.p.m
1929	Ryska Handelsdelegationen, Stockholm	Swir	USSR	11.0	36.1	37500	75
1931	Swedish State Power Board, Stockholm	Vargön	Sweden	4.3	14.1	15200	46.9
1935	OY Rouhiala AB, Jääski	Rouhiala	Finland	17.6	57.8	33000	100
1937	Swedish State Power Board, Stockholm	Stadsforsen	Sweden	27.0	88.5	47700	125
1939	Swedish State Power Board, Stockholm	Hojum	Sweden	31.0	101.6	63900	136.3
1946	Swedish State Power Board, Stockholm	Hölleforsen	Sweden	27.0	88.7	57500	125
1947	Egyptian Government, Cairo	Aswan Dam	Egypt	27.0	88.7	65000	100
1949	Bergeforsens Kraft AB, Sundsvall	Bergeforsen	Sweden	22.75	74.6	48300	115
1950	Swedish State Power Board, Stockholm	Ligga	Sweden	40.5	132.8	105650	125
1953	Swedish State Power Board, Stockholm	Umluspen	Sweden	30.0	98.4	54900	150
1954	Balforsens Kraft AB, Kramfors	Balforsen	Sweden	31.0	101.7	51110	150
1956	Swedish State Power Board, Stockholm	Järkvissle	Sweden	13.6	44.6	59450	75

Among these turbines the Vargön unit is one of the biggest in the world with regard to the dimensions, having a runner diameter of 8 m. (26.2 feet), and the Ligga unit with regard to the output, this being 105,650 HP.

AB KARLSTADS MEKANISKA WERKSTAD KARLSTAD SWEDEN

Representatives in Canada: A. Johnson & Co. (Canada) Ltd., 1428 Shell Tower Building, Montreal 2

Runners for Francis turbines in our works. *Left:* Head 112 ft., output 21,500 h.p., runner diam 9 ft. 6 in., speed 150 r.p.m. (Laforsen Power Station). *Centre:* Head 160 ft., output 47,000 h.p., runner diam 10 ft. 10 in., speed 150 r.p.m. (Storfinnforsen Power Station).

Harnessing water power is a job for NOHAB

Stay ring and spiral casing for a Kaplan turbine being assembled in our works at Trollhättan, Sweden. Head 170 ft., output 87,200 h.p., runner diam 15 ft. 9 in., speed 150 r.p.m. (Lasele Power Station).

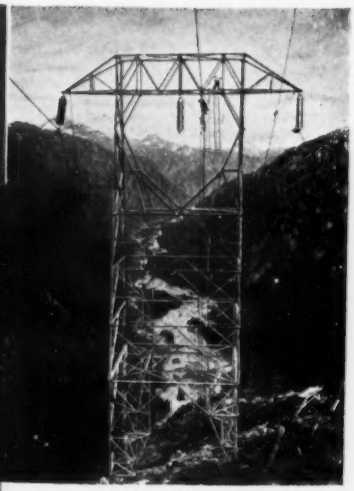
Nydqvist & Holm AB were pioneers in the development of water power over 100 years ago. Technical advance, expansion and research has continued steadily since 1847.
Today our manufacturing programme, which is devoted mainly to equipment for large power plants, includes: water turbines with governors, pipe lines, control valves and gates.
The world's largest Francis turbines with regard to output (for the Stornorrfors water power plant) are being built by us.
Consult NOHAB in your water power planning.

NYDQVIST & HOLM
AKTIEBOLAG
TROLLHÄTTAN · SWEDEN

Cables: NOHAB, Trollhättan. Telex: 5284

Aluminium for transmission lines

a new Handbook



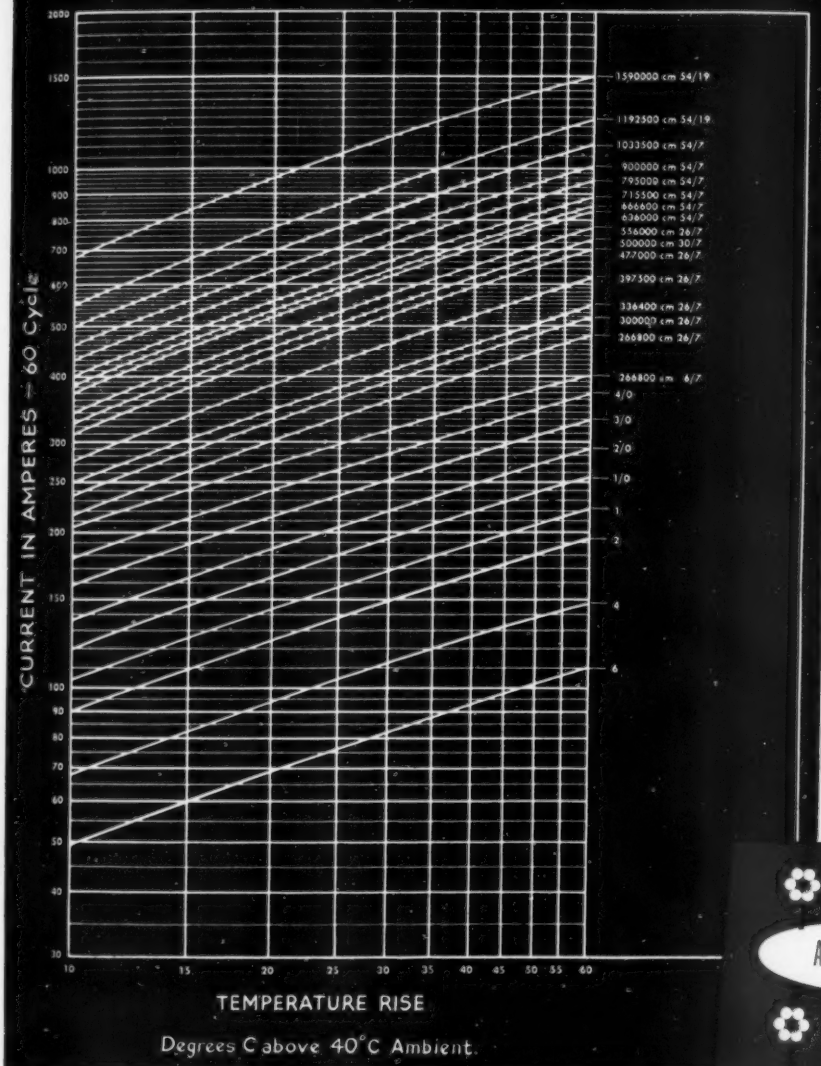
"Stringing operations on Kitimat-Kemano transmission line, British Columbia".

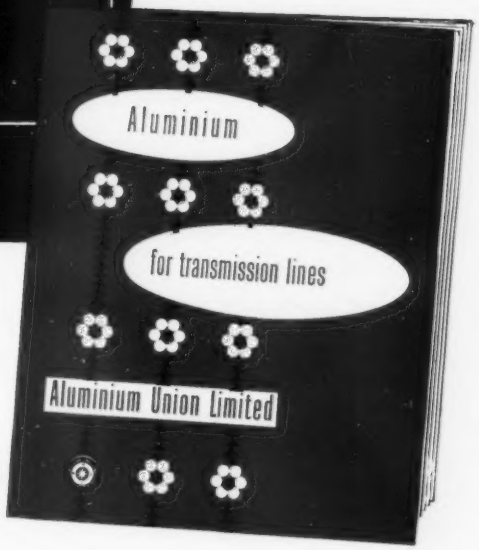
In recent years there has been a growing demand for a comprehensive and up-to-date handbook on the use of aluminium conductors for overhead transmission systems. We have, therefore, produced "Aluminium for Transmission Lines", in which we have condensed the salient features of our experience within the Aluminium Limited Group of Companies, both as users and sellers of transmission line materials.

We believe that this publication will be a valuable asset to those electrical engineers and advanced students who are concerned with this subject. We invite them to write on their business or college stationery *to Aluminium Union Limited, The Adelphi, John Adam Street, London, W.C.2.* when we will be happy to send them a copy.

TEMPERATURE RISE CURVES ON NORTH AMERICAN STANDARD SIZES OF A.C.S.R.— BARE

Air Velocity 2 feet per second (·61 meter per second) Crosswise to Conductors.





Aluminium Union Limited

(Incorporated in Canada)

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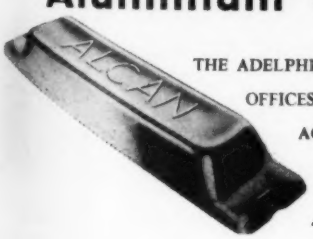
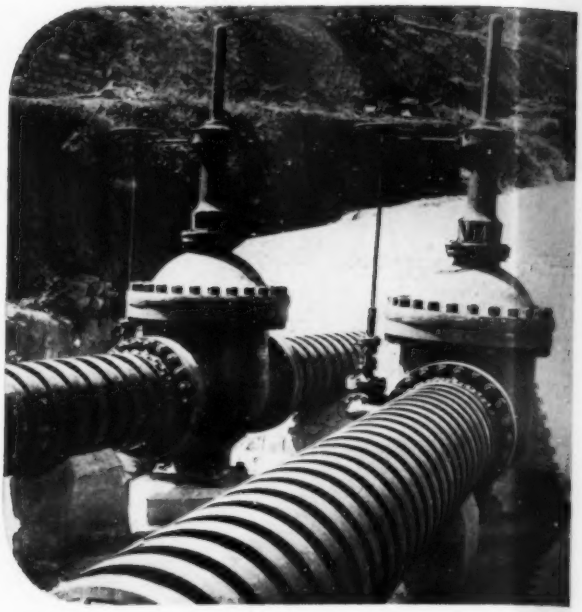


An ALUMINIUM LIMITED Company

In the Pipelines



ISOLATING VALVES

As specialists in the manufacture of all kinds of Water Control Equipment for Hydro-electric installations for many years, our work for this field has included the design and construction of innumerable Pipeline Isolation Valves, of the Sluice type, for high, medium and low head conditions.

The site illustration shows two 26 in. dia. cast steel valves designed to retain a maximum unbalanced pressure of 3,050 ft. head of water; whilst the other photograph shows a 42 in. dia. valve for a pressure of 630 ft. head.

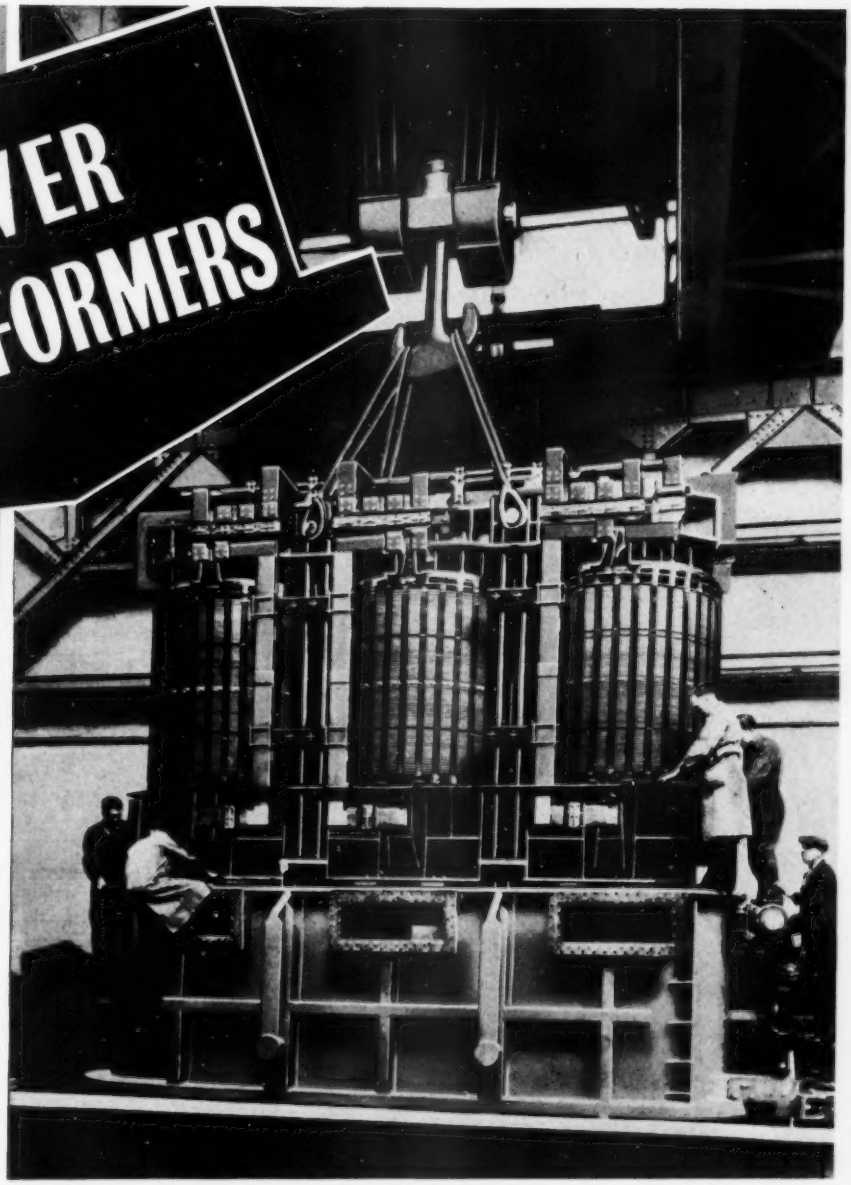
Glenfield

GLENFIELD & KENNEDY, LIMITED, KILMARNOCK

HEAD OFFICE & WORKS · KILMARNOCK, SCOTLAND

VALVE SPECIALISTS AND HYDRAULIC ENGINEERS FOR OVER ONE HUNDRED YEARS

POWER TRANSFORMERS



The millions of kVA of Bruce Peebles Transformers in successful operation today constitute a reliable guide in selecting transformers to meet the demands of tomorrow.

Bruce Peebles manufacture power transformers in the largest sizes for service at all voltages. Typical units in course of manufacture are 120,000 kVA 275,000-volt auto-transformers for the British Super-Grid.

Illustration shows a 75,000 kVA generator transformer in course of erection. It is typical of numbers ordered for direct connection to the generator to operate as a combined unit.

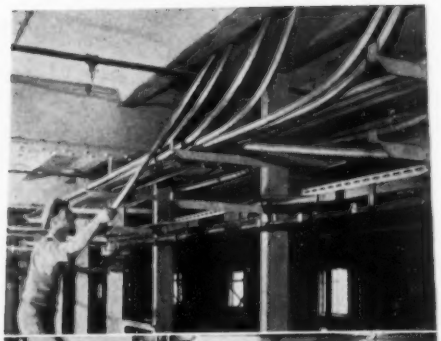
BRUCE PEEBLES

& CO. LTD. · EDINBURGH · SCOTLAND

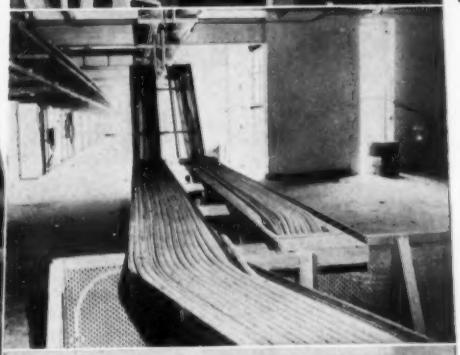
Power Stations

the world over

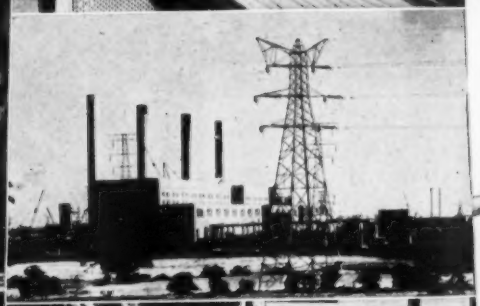
These are a few of the very many Power Station installations carried out by Henley engineers all over the world.



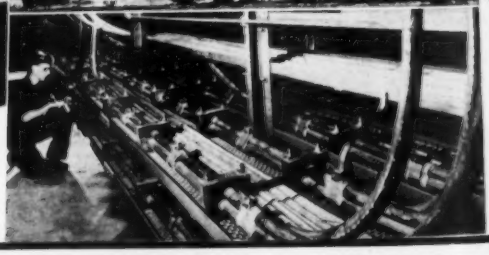
Keadby Power Station, Lincolnshire



Pasir Panjang Power Station, Singapore



Littlebrook 'C' Power Station, Kent

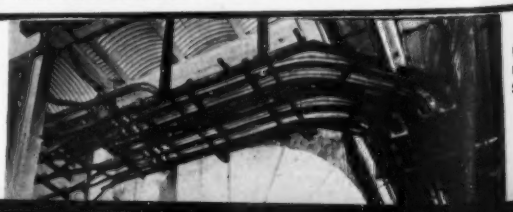


Littlebrook 'D' Power Station, Kent

POWER CABLES BY HENLEY

W. T. HENLEY'S TELEGRAPH WORKS CO. LTD., 51-53 HATTON GARDEN, LONDON, E.C.1 CHAncery 6822

BY APPOINTMENT TO HER MAJESTY THE QUEEN ELECTRIC CABLE MANUFACTURERS



Pretoria 'T' Power Station, South Africa

From Alaska To New Zealand

ALLIS-CHALMERS
Hydraulic
TURBINES

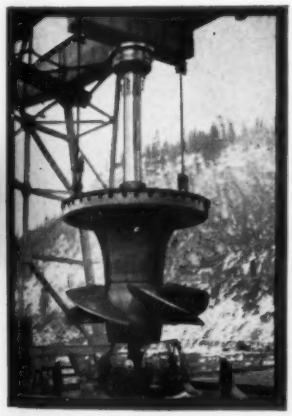
All Over the World

From Petersburg, Alaska to Maraetai, New Zealand, Over 15 Million Hp is Harnessed by Allis-Chalmers Turbines

Allis-Chalmers builds all three principal types of hydraulic turbines — Francis, propeller and impulse. Allis-Chalmers can also supply nearly all the necessary electrical equipment and auxiliaries, including transformers, generators, switchgear, regulators, valves and governors for large units.

You can often make substantial savings by calling in Allis-Chalmers qualified engineers to help you and your consultants select equipment most suitable for your specific needs. Early consultation gives you the advantages of Allis-Chalmers half-century of experience in designing and building hydraulic equipment.

For all or any part of your needs, call the Allis-Chalmers representative near you or write Allis-Chalmers, Power Equipment Division, Milwaukee 1, Wisconsin, U. S. A. Manufacturing plants in United States and Canada.



Propeller Type
Normally used for low heads — up to 100 feet — but in exceptional cases higher. High speed unit offers substantial savings in generator costs.

Francis Type
Used for high heads, up to 1000 feet and sometimes even higher, depending on capacity of the unit, quality of the water and characteristics of the load to be carried.

Impulse Type
For heads as high as pressure pipe lines can be built. Used for heads as low as 200 feet if water conditions make use of Francis type undesirable because excessive wear would result.

A-C ALLIS-CHALMERS

ALLIS-CHALMERS

A-5040

THE MITCHELL CONSTRUCTION COMPANY

CIVIL ENGINEERING CONTRACTORS

a mile a month!

Over 6,000 ft. a month was the record breaking rate at
which tunnels were advanced by the Mitchell Construction Company
during the summer of last year on the contracts
they have for the North of Scotland Hydro-Electric Board at Breadalbane.
Such a rate of tunnel driving is believed to
be without parallel in this class of work anywhere in the world.
It has since been announced that the company have
established a world tunnelling record on these
contracts with a drive of 557 ft. on one heading in seven days.
Throughout the wide range of contracts upon
which they are engaged, similar progress is being maintained, indicative of
the careful planning and sustained sense of urgency which is given
to all work entrusted to the company.

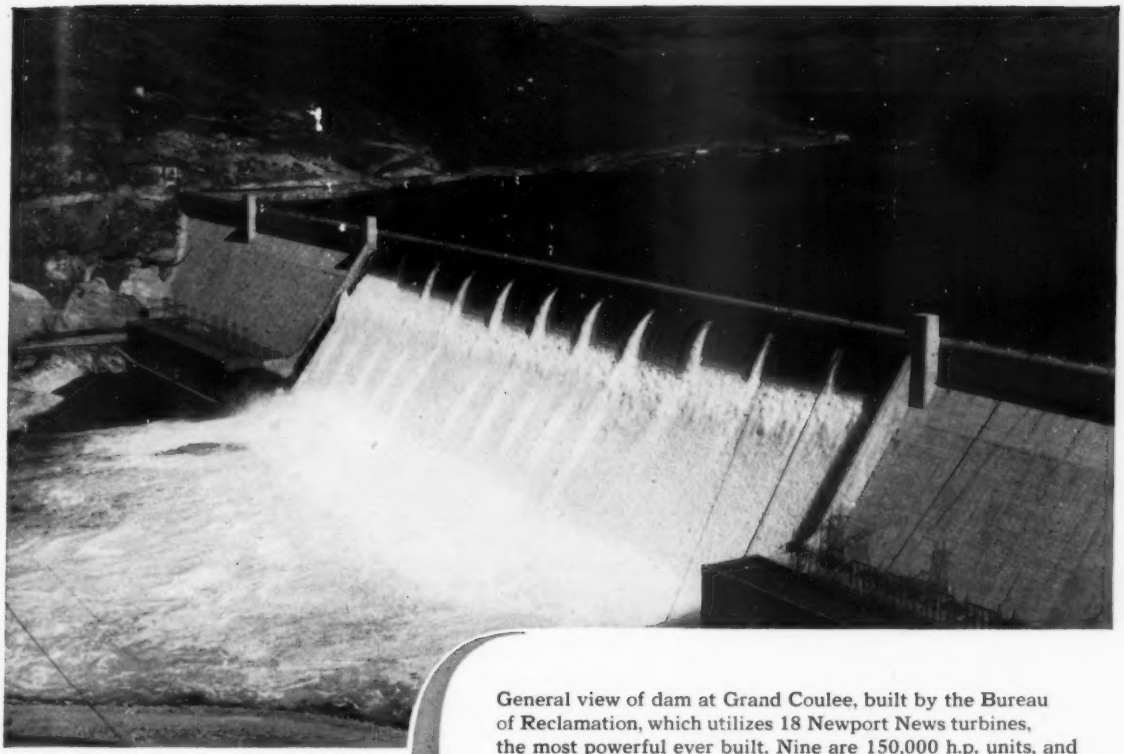
Consulting Engineers: Sir M. MacDonald and Partners

MITCHELL

THE MITCHELL CONSTRUCTION COMPANY

WHARF WORKS PETERBOROUGH and 7 Gower Street London WC1

1957



General view of dam at Grand Coulee, built by the Bureau of Reclamation, which utilizes 18 Newport News turbines, the most powerful ever built. Nine are 150,000 h.p. units, and the other nine are rated at 165,000 h.p. each.

Specialists ... in building Water Power Equipment

Typical Users of Newport News Equipment

PLANT	LOCATION
Boone	Tennessee
Buchanan	Texas
Caonillas	Puerto Rico
Chief Joseph	Washington
Clark Hill	South Carolina
Deer Lake	Newfoundland
Folsom	California
Fort Patrick Henry	Tennessee
Hiwassee	Tennessee
Hoover	Nevada
J. H. Kerr	Virginia
Jim Woodruff	Florida
Lower Salmon	Idaho
Norris	Tennessee
Rock Creek	California
Santee-Cooper	South Carolina
C. J. Strike	Idaho
Whitney	Texas
Wilson	Alabama

Turbines designed and built for the world's largest development at Grand Coulee... and for other hydroelectric installations in America and various parts of the world... bespeak the skill and facilities offered by Newport News.

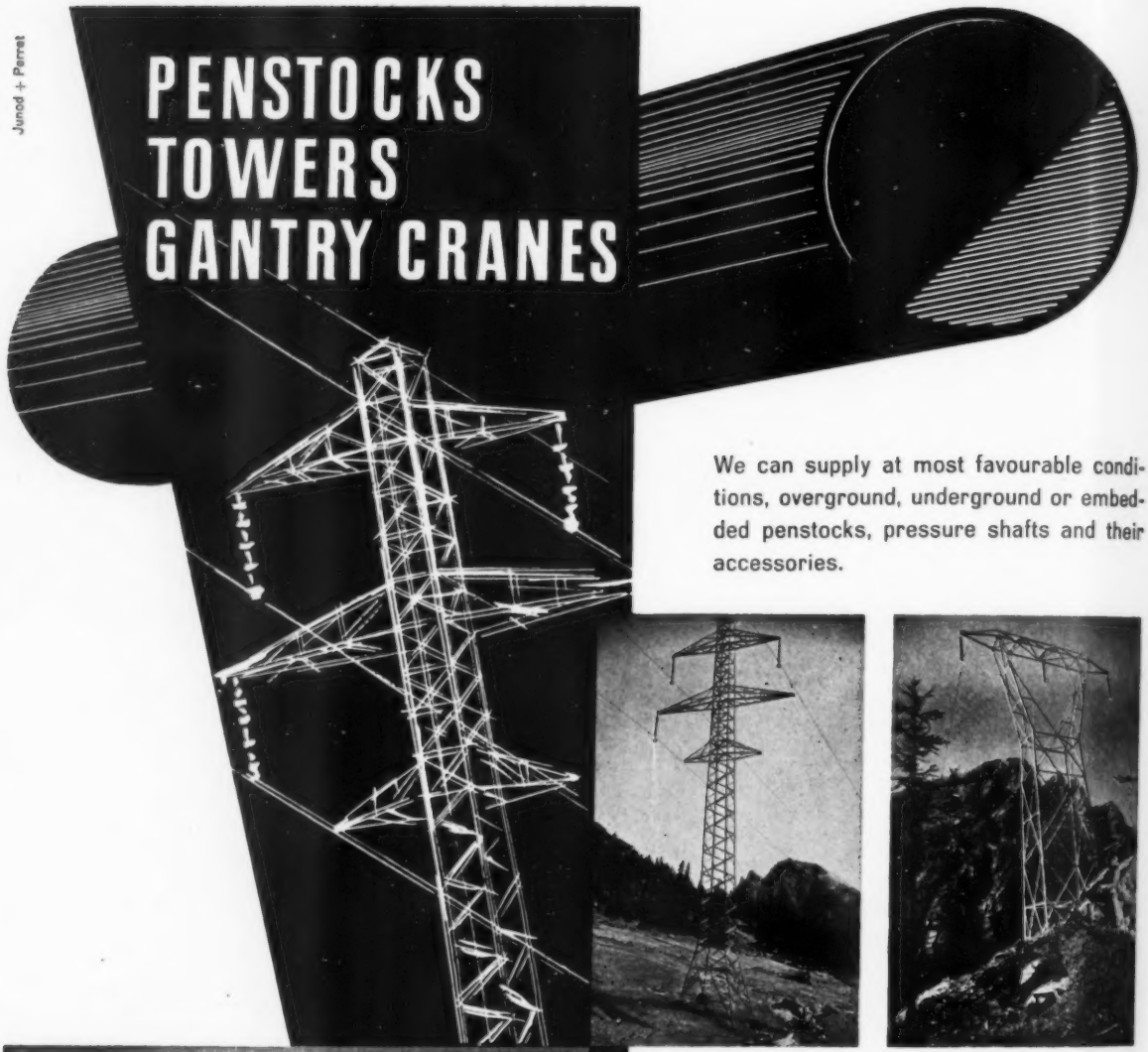
This trained organization has filled hydroelectric turbine contracts with an aggregate rated output of 7,000,000 horsepower.

Other equipment designed and built by Newport News includes penstocks, pressure regulators, valves, pumps, gates and rack rakes. Upon request, a copy of our illustrated booklet entitled "WATER POWER EQUIPMENT" will be sent to you.

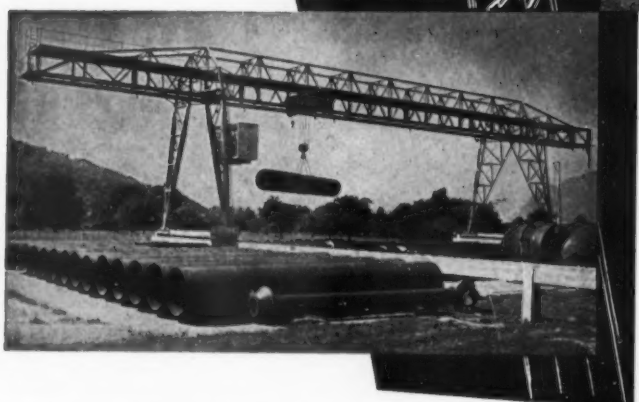
Newport News
SHIPBUILDING AND DRY DOCK COMPANY
Newport News, Virginia

Junod + Perret

PENSTOCKS
TOWERS
GANTRY CRANES



We can supply at most favourable conditions, overground, underground or embedded penstocks, pressure shafts and their accessories.



Towers for electric transmission lines, for teleferics or radio aerials.
Steel structures for buildings.
Reservoirs of any shape and dimensions.

Gantry crane, lifting capacity 3 to 25 tons, distance between rails 36 m., 2 overhangs of 12 m., total length 60 m.

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GIOVANOLA FRÈRES S. A., MONTHEY (VS) SUISSE

Aluminium alone

AWCO's Port Tennant Works is the largest in Great Britain devoted solely to the production and stranding of aluminium and aluminium alloy wire. An important advantage of such specialization is the elimination of all risk of contamination by particles of other metals during processing. Our modern plant, backed by full laboratory control, ensures the efficient manufacture of a high quality product, enabling us to give an unrivalled customer service.

11-die continuous wire drawing machine reducing ⅜" diameter rod to ⅛" diameter wire.

AWCO produces :

STRANDED ELECTRICAL CONDUCTORS in all-aluminium, steel-cored aluminium and Silmalec (aluminium alloy)

WIRE for the manufacture of insulated cables

WIRE for aircraft and general engineering

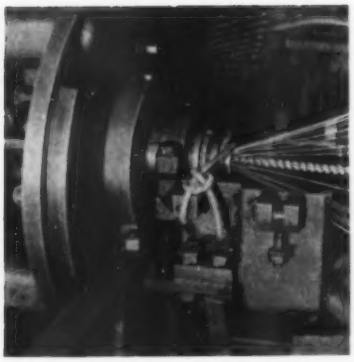
HOT-ROLLED ROD

AWCO

ALUMINIUM WIRE & CABLE CO LTD

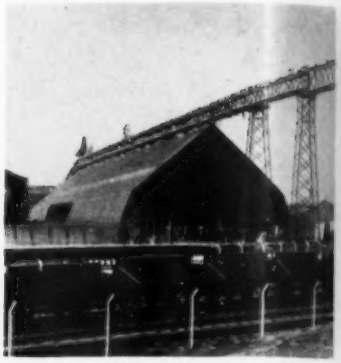
Britain's Largest Manufacturers of Aluminium Wire and Conductors
Head Office & Works: PORT TENNANT, SWANSEA, GLAMORGAN
Sales Office: 30 CHARLES II STREET, ST. JAMES'S SQUARE, LONDON, S.W.1 TRAfalgar 6441
And at 6 LIVERY STREET, BIRMINGHAM, 3 Central 7629

AP 210/22



The first forming die ; copper wires are applied to the hollow gas duct to form the conductor.

Galvanized steel armouring wires being applied for protection.



The gantry used to convey the cables from the storage shed to the "Ocean Layer".

$3,500,000 POWER CA
SUCCESSFULLY CO

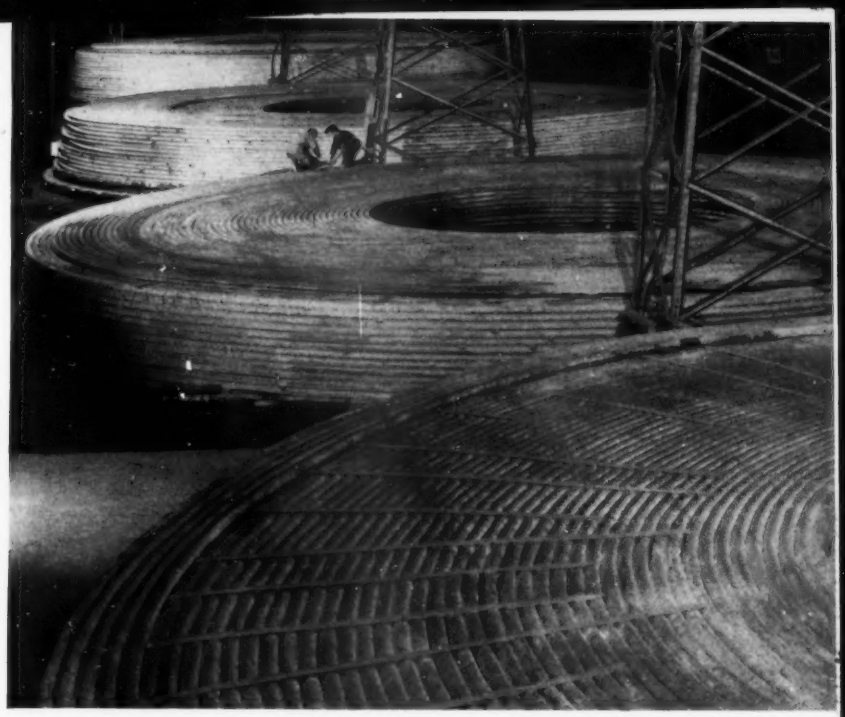
Five 15 mile submarine cables laid across the Georgia Strait, B.C.

THE "OCEAN LAYER"

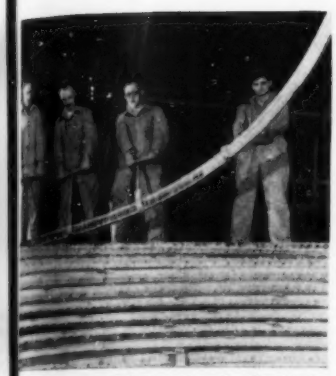
The 4,600 ton "Ocean Layer," most up-to-date cable-laying ship in the World, was specially chartered for this project. It is the first British ship to be fitted with a Pleuger active rudder, housing an auxiliary propeller. The Pleuger rudder greatly increases manoeuvrability, essential in cable-laying work.

THE 138kV CABLE

Four inches in diameter and weighing 52 lbs. per yard, this is a single-core, 0.35 sq. in. hollow core copper conductor, gas-filled cable, operating at a three-phase voltage of 138kV with a gas pressure of 300 lbs./sq. in.



Interior of the storage shed showing the lengths of cable coiled down prior to loading.



Coiling down one of the long lengths of cable for Vancouver into the storage shed.

R CABLE CONTRACT
Y COMPLETED!

B.C.

THIS WAS THE PROBLEM:

The British Columbia Electric Company required a 120 MVA power link between the mainland and Vancouver Island. The transmission scheme recommended included, as the main crossing, the provision of five 138,000 volt submarine cables *each in a continuous length of over 15 miles*.

The manufacture, transportation and laying of such cables was considered to be practically impossible by many in the electrical world.

" *Look at the manufacturing difficulties,*" they said, " *the continuous lengths of strand; the insulation to be applied; the problems of continuous lead sheathing and subsequent armouring!* "

THIS WAS THE ANSWER:

After very careful consideration of the problems involved, BICC submitted a tender and were awarded the contract. New plant was designed and installed in one of the Group's factories close to the Manchester Docks. As the cables left the production line they were carried by means of a 45 feet high gantry with power winches, to an adjacent storage shed where they were fully tested. Thence, by a continuation of the same gantry they passed over the docks area to be coiled down into the cable tanks of the *Ocean Layer*—the World's most up-to-date cable-laying ship.

Now, after only two and a half years, this joint Anglo-Canadian undertaking has been completed. The cables have been manufactured, laid, connected and commissioned on schedule.

Thanks to the courage and enterprise of the British Columbia Electric Company and the engineering ability of the BICC Group, the swiftly-growing and highly important timber, pulp and paper industries of Vancouver Island can now obtain adequate power from the hydro-electric generating stations on the mainland.

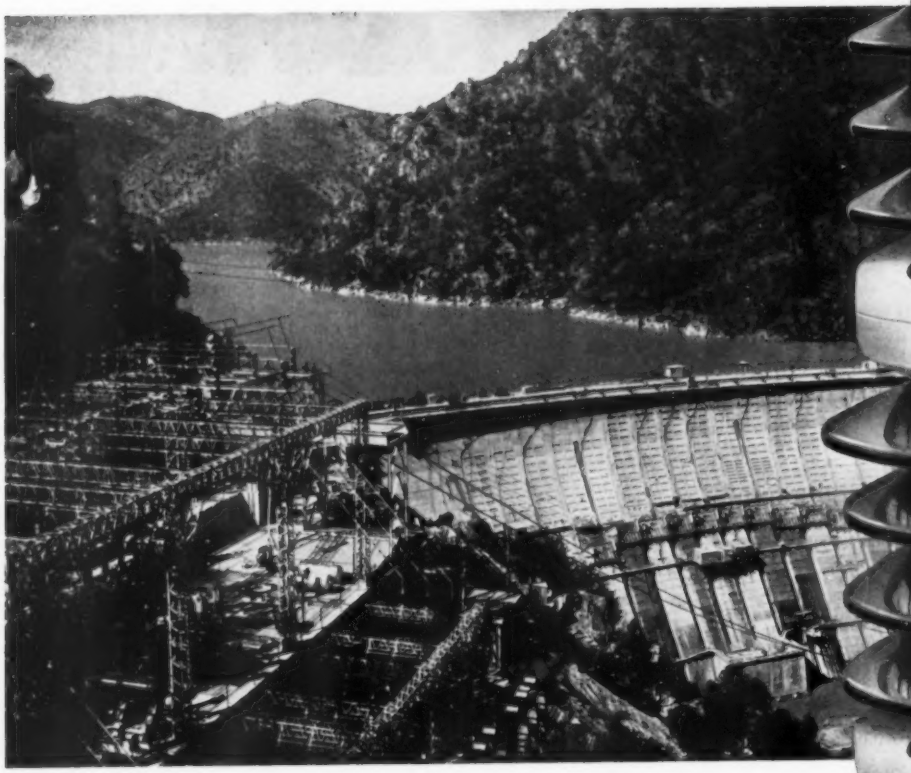
Only BICC had the resources, the capital and the confidence to undertake and complete such an ambitious project—worth three and a half million dollars. *Only BICC have the facilities to do this again. To manufacture long, continuous lengths of power cable—and install them anywhere in the World!*

BICC CABLES

THE name for cables-everywhere

BRITISH INSULATED CALLENDER'S CABLES LIMITED, 21 Bloomsbury Street, London, W.C.1, England

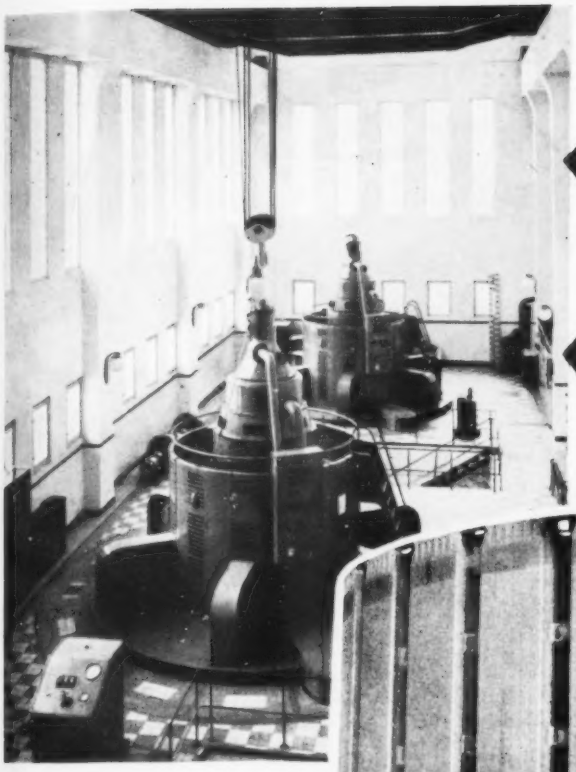
S.P.P. Post Insulators were used for the New South Wales Public Works Department for Burrinjuck Sub-Station.

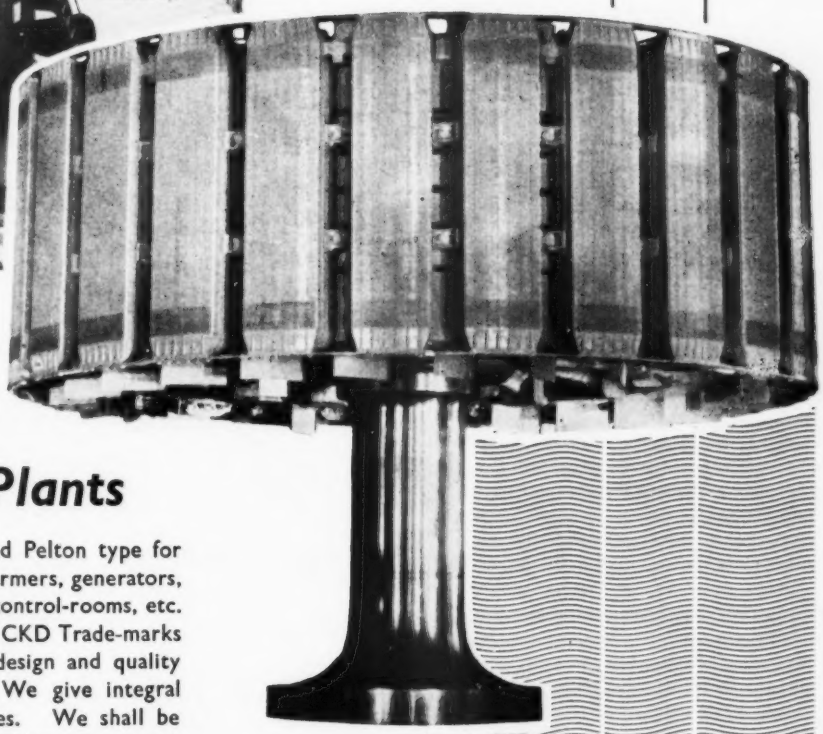


The Burrinjuck 132 kV Switching Station was equipped with Cylindrical Post Insulators type P.703. This is one of many stations on the New South Wales Public Works Department system equipped throughout with S.P.P. Post Insulators for 110 kV and 66 kV.

STEATITE & PORCELAIN PRODUCTS LTD.

Stourport-on-Severn, Worcestershire. Telephone Stourport 111. Telegrams : Steatain, Stourport.





Complete Equipment for Water Power Plants

Turbines of the Francis, Kaplan and Pelton type for various heads and outputs, transformers, generators, outdoor and indoor switch-gear, control-rooms, etc. The World-renowned SKODA and CKD Trade-marks guarantee the first-class technical design and quality of equipment supplied by us. We give integral guarantees for complete deliveries. We shall be pleased to advise you in all your problems connected with the projection of water power plants.

TECHNOEXPORT

FOREIGN TRADE CORPORATION FOR EXPORT OF COMPLETE INDUSTRIAL PLANTS

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CZECHOSLOVAKIA

Water has its uses . . .

COMMON FROG

Found abundantly all over the British Isles, Rana temporaria, the common frog, feeds on insects, worms, slugs etc., taking its food mainly at night. Frogs breed as soon as they emerge from their winter hibernation and then leave the water, living in damp places on land. In coloration, the common frog is most variable and may be grey, olive, brown yellow or red above, with darker spots and markings.

The placid pools, lakes and slow-moving streams beloved by frogs provide water for larger rivers that in turn can become one of man's chief sources of power.

Wherever there is falling water a water turbine can be installed—the simplest and most reliable form of prime mover—no fuel bills, long life, little maintenance and requiring only unskilled attention.

GILKES are specialists in the field of small hydro-electric units; we can supply installations to operate on any head from 3 feet to 5,000 feet (or 1 metre to 1,500 metres) and to develop any output up to 1,000 kilowatts on low heads or 10,000 kilowatts on the higher heads.

If you wish to make the fullest and most economic use of your potential water power, let GILKES advise you.

1,400 B.H.P. Francis turbine for New Zealand

GILBERT GILKES & GORDON LTD

WATER TURBINE & PUMP MANUFACTURERS

KENDAL Telephone: Kendal 28 ENGLAND

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On it goes . . .

and years of protection lie ahead whether it be Bridge, Barn, Dock or Derrick. If you are a maintenance man it will pay you to know more about "BITUMASTIC" coatings. A copy of our latest Brochure will be sent on request.

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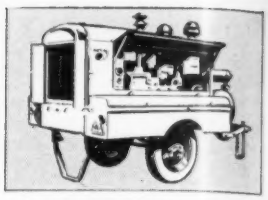
Anti-Corrosive ***SOLUTIONS & ENAMELS***

"BITUMASTIC"

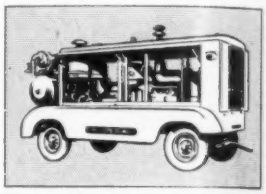
WAILES DOVE BITUMASTIC LTD · HEBBURN · CO. DURHAM

H129
2130

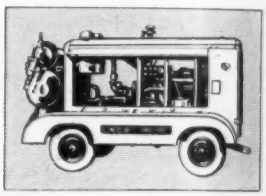
For the construction of new licensed premises at Peckham, the Contractors, Holliday & Greenwood Ltd., use the new CP Power-Vane rotary compressor.



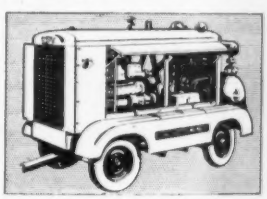
Model 125-RO-2 shown in the photograph will operate two medium breakers or rock drills.



Model 600-RO-2 powered by Rolls-Royce oil engine is an ideal unit for big construction schemes.



Model 365-RO-2 powered by Rolls-Royce, is a plant of ample margin for average construction needs.



Model 210-RO-2 is a medium capacity plant suitable for 'four-tool' operation.

This compressor slashes maintenance and repair costs

Incorporating the most important design advances since portable air compressors came into general use, Power-Vane rotary compressors eliminate clutch, crankshaft, valves and pistons, and are fast becoming the first choice of Contractors on every type of job. Maintenance and repair time is virtually eliminated.

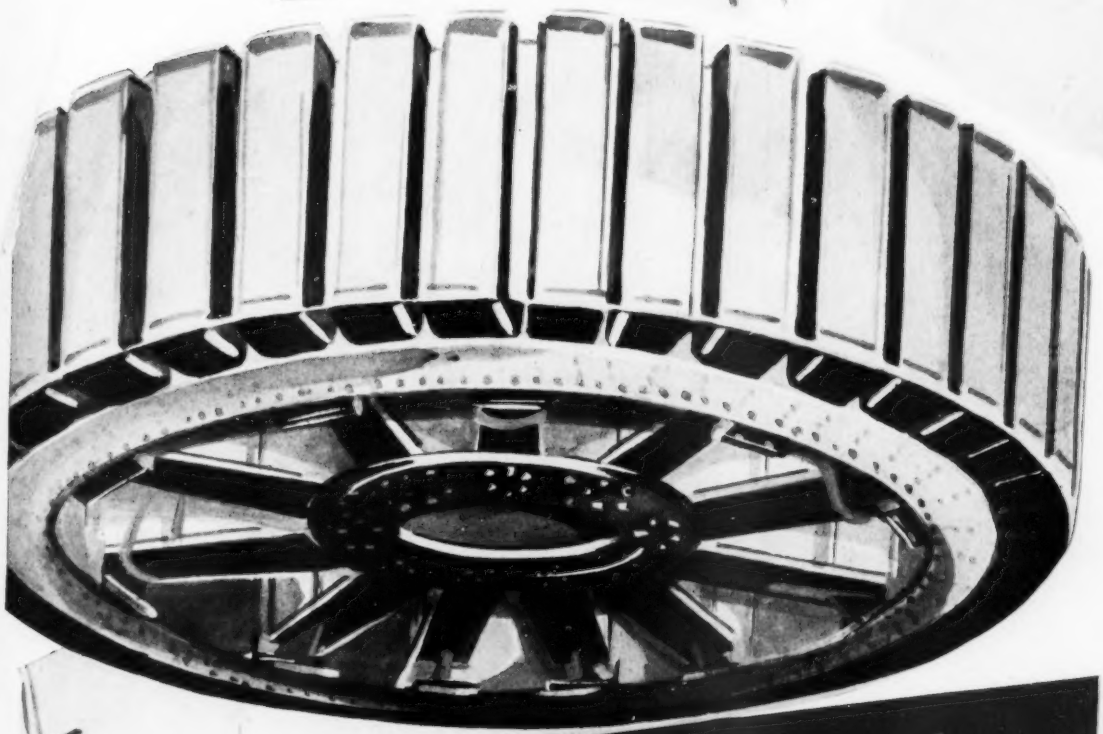
The entire unit runs in oil and is oil cooled. Fully automatic safety devices prevent damage by oil pressure failure or excessive temperature. Available in a wide range of types for different applications, the Power-Vane Compressor is something every Plant Engineer should know about. Ask for Catalogue 58c.

POWER VANE ROTARY COMPRESSORS

MANUFACTURED BY CONSOLIDATED PNEUMATIC TOOL CO. LTD · 232 DAWES ROAD, LONDON, S.W.6

CPT2

undred-and-seventy Tons



. . . the weight of this salient-pole rotor. Revolving at 136.4 rev/min it will help generate electricity in a modern AEG water-power alternator.

These rotors can have peripheral speeds of up to 620 ft/sec.; in service, the load on the thrust bearing may reach 1200 tons and above.

The design of every component part of these AEG alternators, both large and small, gives factual evidence of much practical experience gathered over many years. The cumulative effect of continued and patient detail work has greatly contributed to the world-wide reputation of AEG.

AEG

7427 e

ALLGEMEINE ELEKTRICITÄTS-GESELLSCHAFT

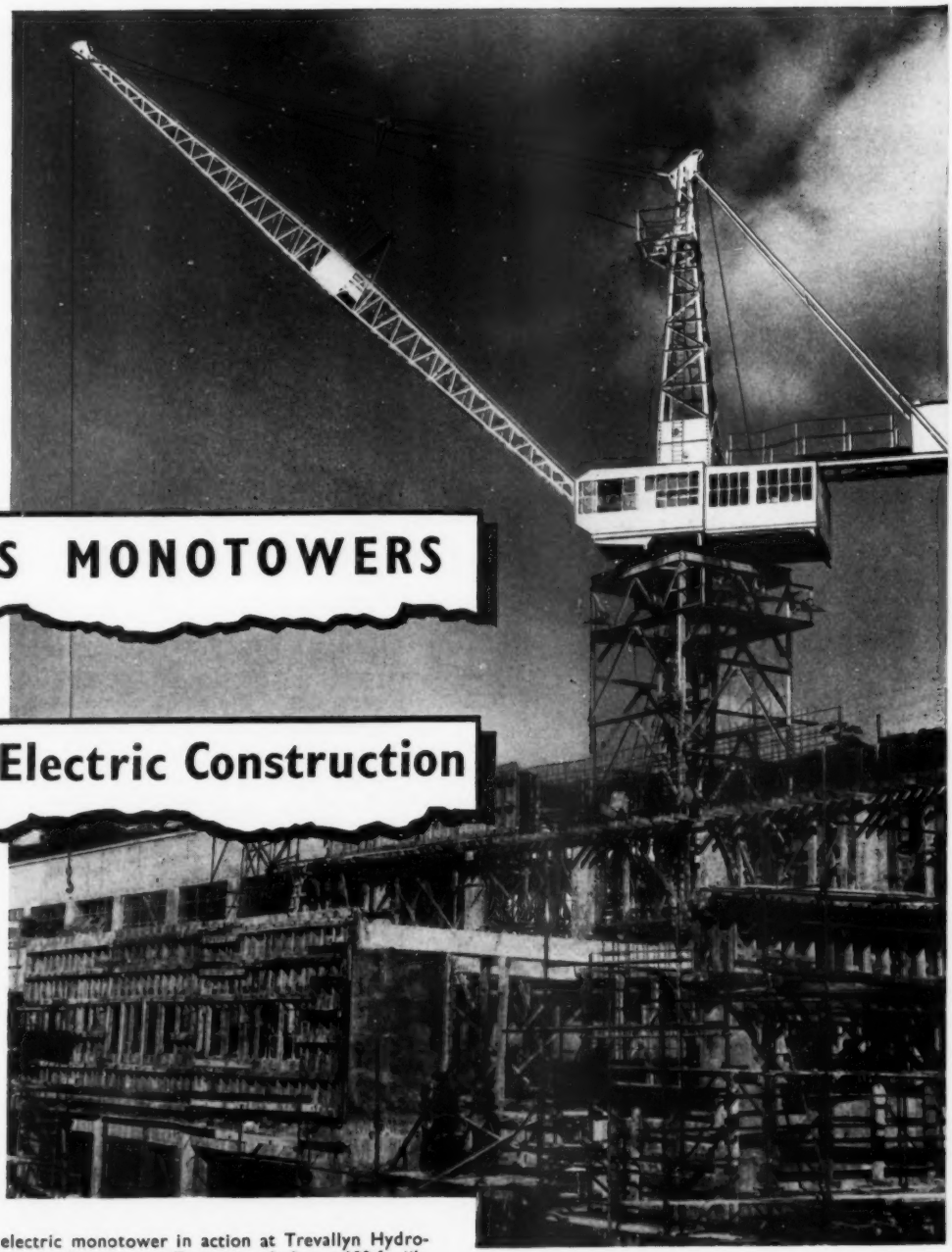
Berlin (West) EXPORT DEPARTMENT Frankfurt (Main)

ESCHER WYSS

High-pressure Francis runner for Fionnay Power Station (Switzerland)
Output **63,000 H.P.**, speed 750 r.p.m., max. head **455 m.**

Similar high-pressure Francis turbines are in course of manufacture for the Safienplatz Power Station of Messrs. Zervreila A.G. (Switzerland)
Output 60,000 H.P., speed 750 r.p.m., max. head 422 m.

ESCHER WYSS LTD., ZURICH (SWITZERLAND)



BUTTERS MONOTOWERS

in Hydro-Electric Construction

This crane is a 5 ton electric monotower in action at Trevallyn Hydro-Electric Power Station near Launceston, Tasmania. It has a 100 ft. jib, 80 ft. tower, and handles 5 tons at 75 ft. and 1¼ tons at 100 ft. radius. The ideal crane for erection of dams and high buildings generally, with all the dependability of the Butters product.

BUTTERS BROS. & CO. LTD.

MACLELLAN STREET, GLASGOW, S.1.

Telephone: IBROX 1141 (6 lines) *Telegrams: "BUTTERS, GLASGOW."*

AND AT LONDON, BIRMINGHAM & NEWCASTLE

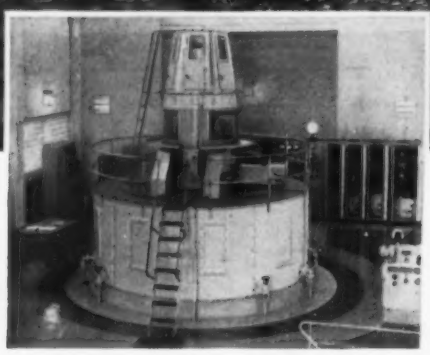
HYDRO-ELECTRIC EQUIPMENT

Power for New Zealand by

B T-H

New Zealand mutton and wool from the district of Otago, in South Island, is mainly exported through Dunedin. 48,500 kVA of electric power is provided for this flourishing city by harnessing the Waipori river at four points in its course from Lake Mahinerangi. This river has provided electric power since the beginning of the century, but the Dunedin City Council have developed it into a major project to match increasing prosperity. BTH equipment plays a large part in this scheme, harnessing the power of natural resources.

A general view of No. 4 dam.



One of the BTH 9,000-kVA, 6.6-kV alternators.

The present No. 1 station, begun in 1928, was the first fully-automatic hydro-electric power station to be equipped by BTH. No. 2 station was equipped with four BTH alternators between 1928 and 1939. Stations 3 and 4, with BTH 9,000-kVA, 6.6-kV alternators, were officially inaugurated in March 1955. All stations have BTH switchgear and automatic control equipment.

BRITISH THOMSON-HOUSTON

THE BRITISH THOMSON-HOUSTON COMPANY LIMITED · RUGBY · ENGLAND

Member of the AEI group of companies.

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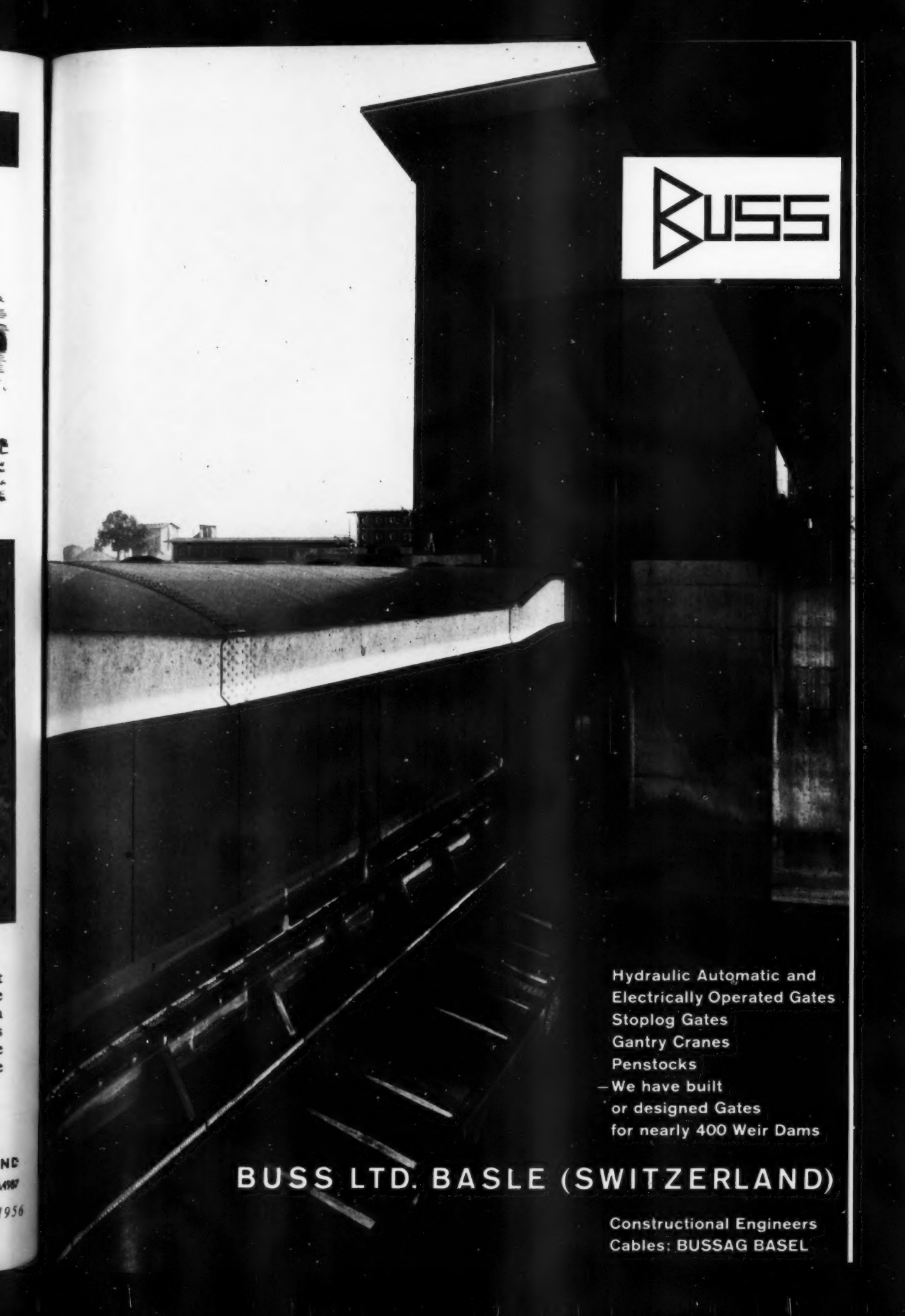
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Hydraulic Automatic and
Electrically Operated Gates
Stoplog Gates
Gantry Cranes
Penstocks
—We have built
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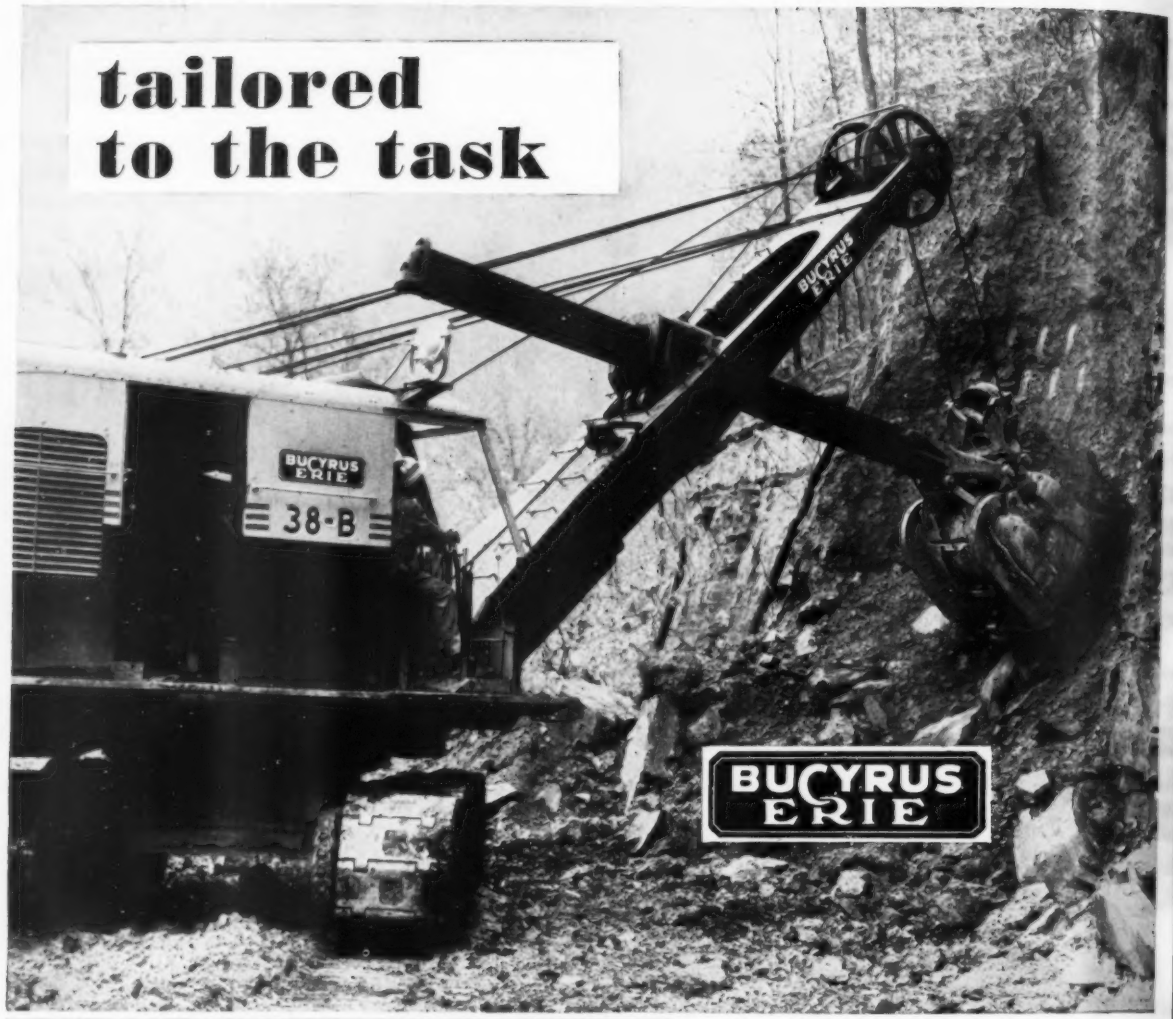
BUSS LTD. BASLE (SWITZERLAND)
Constructional Engineers
Cables: BUSSAG BASEL

tailored to the task



Each size of Bucyrus-Erie excavator is individually designed all the way through from caterpillar tracks to boom-point sheaves for a definite size payload. For example, in every detail of this power-packed 38-B 1½ cubic yard shovel the strength is there to meet demands. Furthermore, with main machinery, power unit and mounting all perfectly matched to front-end capacity, the danger of over-stressing gears, shafts, drums, clutches, ropes, etc., is reduced to a minimum.

As shovel, dragline or dragshovel you can depend on a 38-B for hard work.

BUCYRUS—ERIE

BUCYRUS-ERIE CO · SOUTH MILWAUKEE · WISCONSIN · U.S.A. ★ RUSTON-BUCYRUS LTD · LINCOLN · ENGLAND

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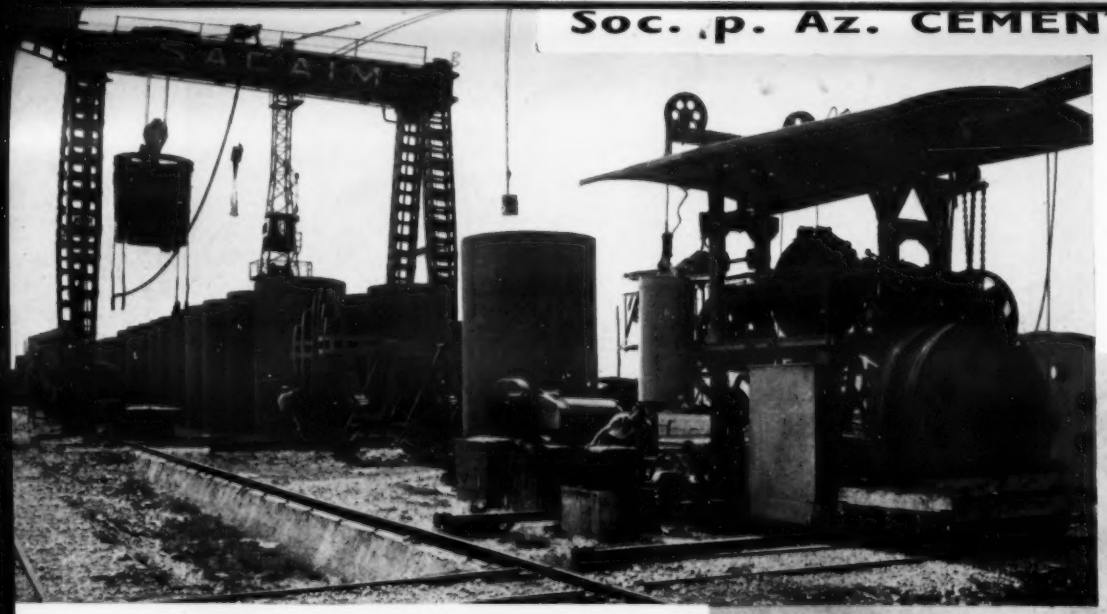
Soc. P. Az. CEMENTI ARMATI Ing. MANTELLI



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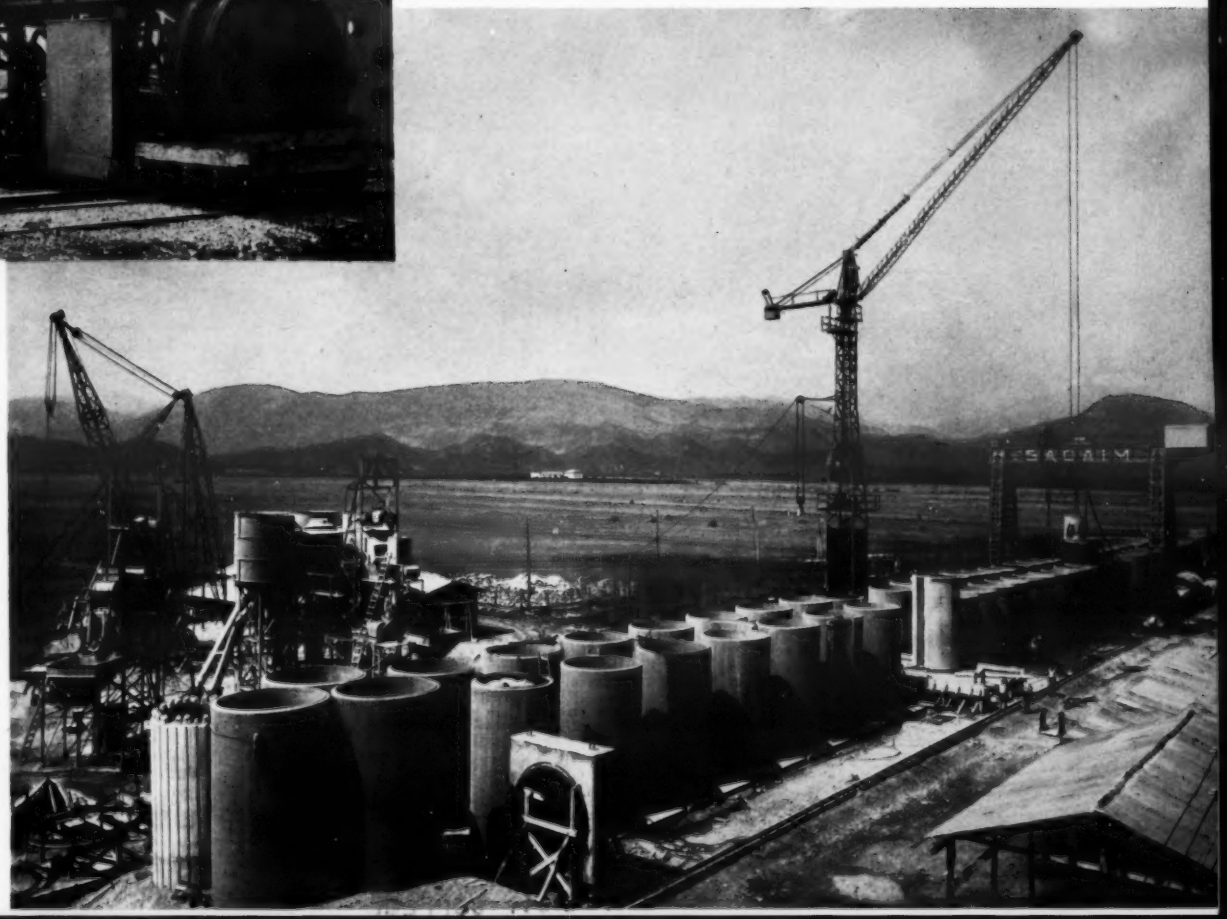


Prestressed reinforced concrete Penstocks (internal diameter 2.60 metres) for the Meduna hydro-electric station of

S.A.I.C.I.

SOC. AGRICOLA INDUSTRIALE PER LA CELLULOSA ITALIANA di MILANO

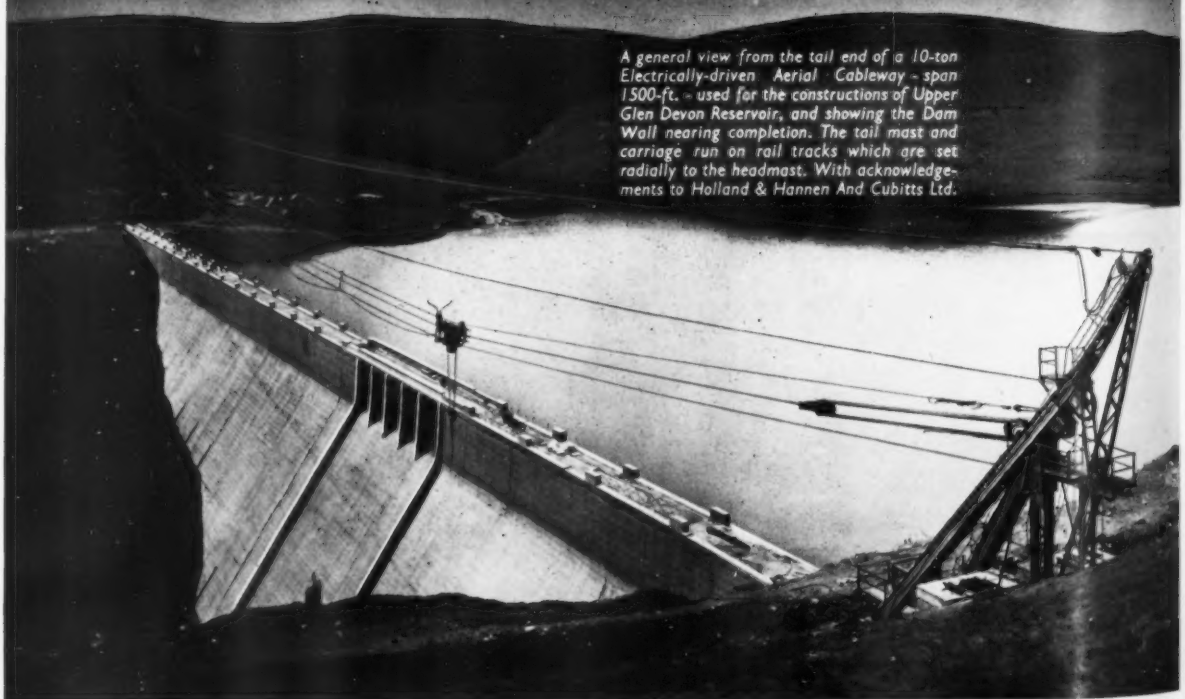
well on top of schedule

MOVEMENT of materials . . . . . that's the secret of meeting schedules on great projects. Getting the stuff in, putting the machinery on the job, - half the battle is won when movement is unhampered, when the equipment which handles the gear does so with unfailing reliability.

Henderson Cableways fit the description. Not only is each component built to the highest degree of engineering skill - Henderson Cableways are undoubtedly the most economical method of moving big loads on the majority of dam, barrage, bridge or viaduct contracts. Confirmation of this fact lies in the considerable number of cableways we have installed at vast projects throughout the world.

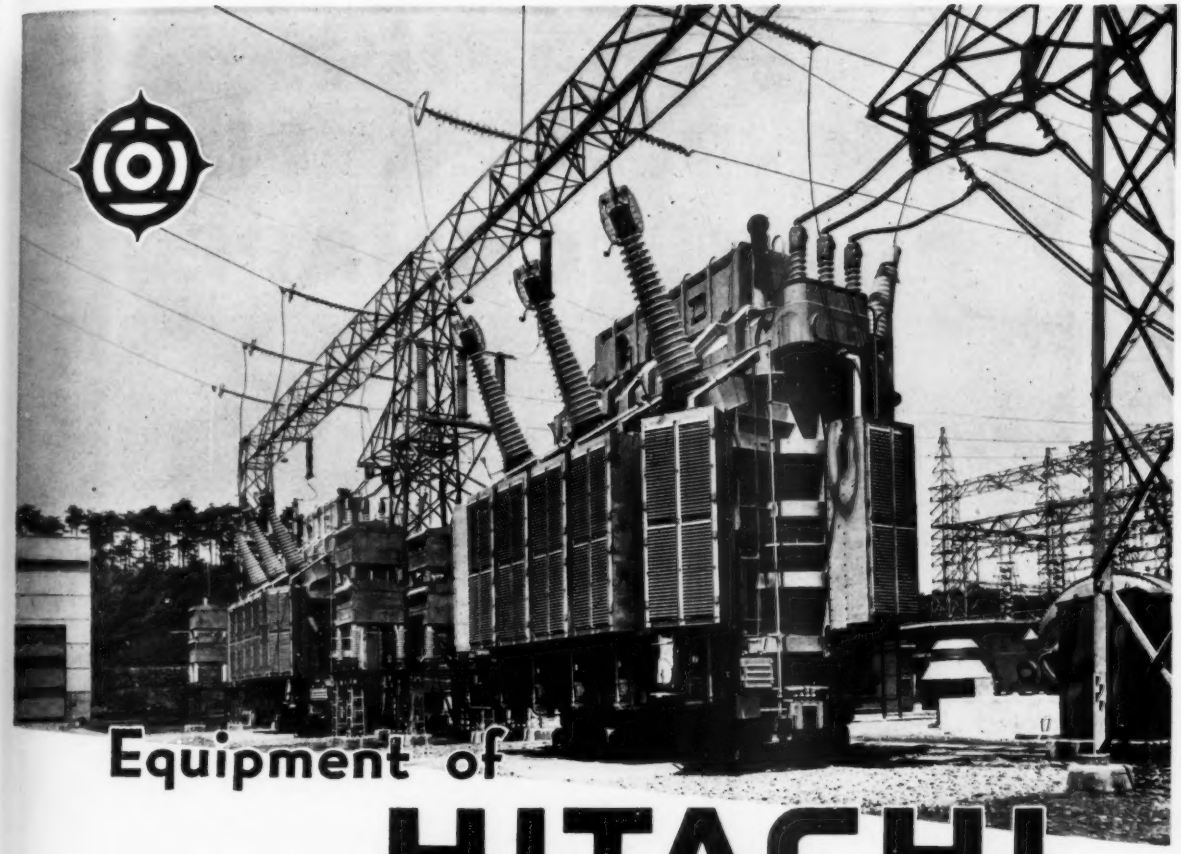
Henderson *CABLEWAYS*

lifelines to movement



A general view from the tail end of a 10-ton Electrically-driven Aerial Cableway - span 1500-ft. - used for the constructions of Upper Glen Devon Reservoir, and showing the Dam Wall nearing completion. The tail mast and carriage run on rail tracks which are set radially to the headmast. With acknowledgements to Holland & Hannen And Cubitts Ltd.

JOHN M HENDERSON AND CO LIMITED KINGS WORKS ABERDEEN



Equipment of HITACHI

for Substation Service

The photo shows Hitachi's 156,000 kVA super high-voltage transformers in service at the Nishi Tokyo Substation of the Electric Power Development Co. These outdoor type transformers are of 3-phase, 3-winding, core type, forced oil and air-cooled system. The high and medium voltage winding of these transformers is provided with a Hitachi patent controsurge winding to increase their series electrostatic capacity and improve impulse voltage characteristics.

Rated output (Equivalent, 156,000 kVA)
- First ..... 120,000 kVA
- Second ..... 132,000 kVA
- Third ..... 60,000 kVA

Frequency ..... 50 cycles

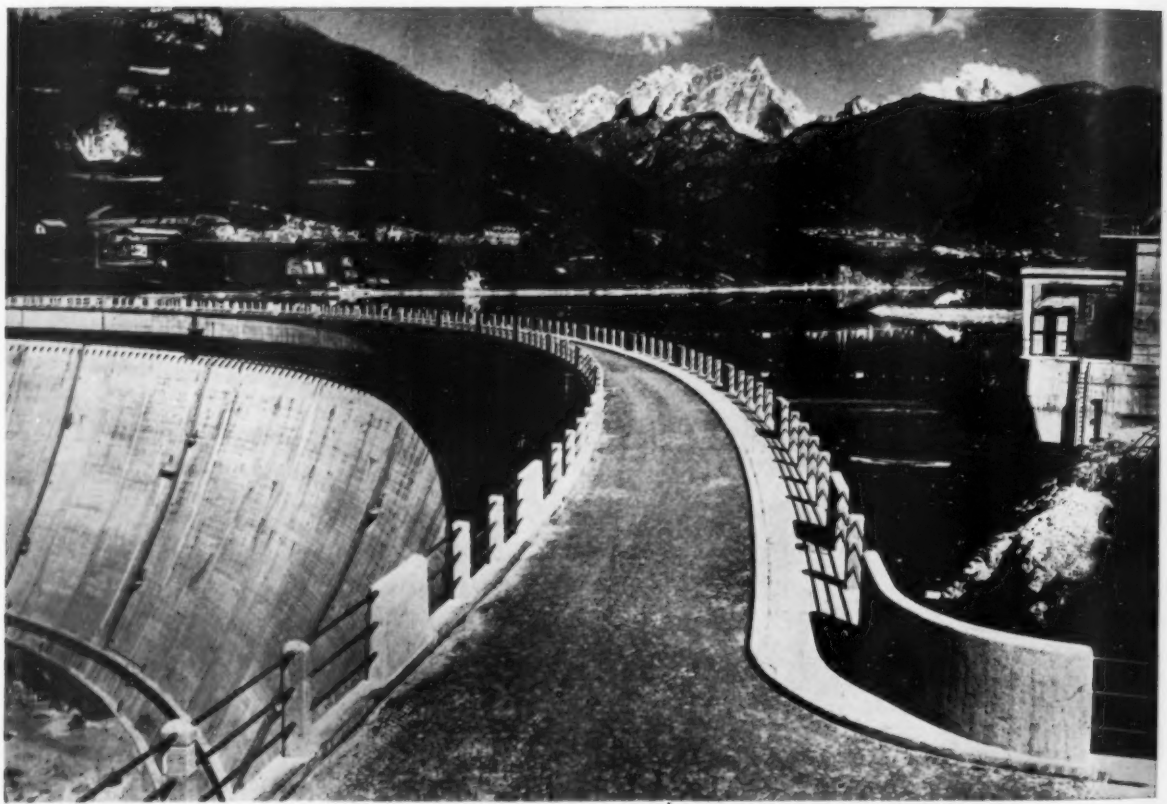
Voltage
- Primary ..... F275—R262.5—F250 kV
- Secondary ..... 147,000 V
- Tertiary ..... 12,600 V

Hitachi, Ltd. also supplied there the circuit breakers of the Hitachi Contrarc type. Designed as the self-extinguishing type, they have also a forced extinguishing mechanism, which ensures the constancy of the interrupting characteristic regardless of the magnitude of the interrupting current. It is another feature of these apparatuses that by the use of the four-point simultaneous interrupting device, small currents such as charging current, exciting current, etc. can be interrupted positively. Also, an oil current extinguishing system which works on compressed air is used. This eliminates re-ignition completely.

Hitachi, Ltd.
Tokyo Japan

Cable Address: "HITACHY," TOKYO

ITALY'S BIG WATER-POWER PLAN IS TAKING SHAPE



The Pieve di Cadore Dam in the Dolomites. This forms a reservoir of over 2 million cubic feet of water. The dam is 370 ft. high with a length across the top of 1,015 ft. Developed by Società Adriatica di Elettricità, SADE.

The Dolomites and the Appenines are taking on a new role. One by one their fast-flowing mountain rivers are being harnessed to provide the whole of Italy with a cheap, abundant supply of power. Under an immense water-power development programme that has been going on since 1948, dams have been constructed, tunnels driven under mountain ranges and power houses installed above and below ground. The results have been impressive, indicative of the speed with which the plan is taking shape. The latest available figures, those of 1955, show Italy's installed hydro-electric capacity at over 9 million kilowatts.

Two Atlas Copco drills engaged on benching operations for the foundations of the Val Martello Dam. Contractors: Ing. Torno.

Atlas Copco supply 85 % of the drills

In 1950 Atlas Copco rock drills and Sandvik Coromant steels were introduced for the first time into Italy. In that year they accounted for 10 per cent of the drilling equipment engaged on the hydro-electric projects. As on many other giant construction projects throughout the world the performance of this lightweight drilling unit was outstanding, resulting in its wide-scale adoption. *By 1955 over three-quarters of the rock drills working on Italian hydro-electric projects were Atlas Copco machines and nearly half the steels, Sandvik Coromants.*

Thirty million cu. ft. of rock a year

For the past five years Atlas Copco drills and Sandvik Coromant steels have been responsible for the excavation of 30 million cubic feet of rock *per year* on Italian hydro-electric projects. Considering the small-sized sections of Italian tunnels, this amount of rock means miles and miles of tunnelling a year. Other Atlas Copco equipment in wide use on Italian power projects includes mine loaders and air compressors.

The world's leading drilling unit

On hydro-electric projects from India to Norway, Australia to Brazil, Atlas Copco drills and Sandvik Coromant steels are in operation. These drills and steels were developed to work together as a lightweight drilling unit. Since its introduction in the early 'forties it has extensively replaced the heavy bar-rigged drifter. Today, Atlas Copco drills and Sandvik Coromant steels are the world's most widely-used pusher leg drills and integral steels, responsible for the drilling of no less than one billion feet annually.

More drills in action at the face

Atlas Copco light rock drills are compact, *one-man* machines. That enables you to put *more* drills into action at the face at one and the same time. More drills mean *faster* times each round and, because they're one-man machines, a reduction—in most cases—of total shift crews by at least a third. At the same time the original capital outlay and general maintenance costs are far lower than for those of heavy equipment. So, if you want to do the job faster, and at lower cost, the Atlas Copco light rock drill is *your* machine.

Extra-tough Sandvik Coromant steels

At the drilling end of Atlas Copco rock drills you'll find Sandvik Coromant steels. Their high, uniform quality guarantees a constant rate of progress with a minimum of costly and troublesome interruptions during drilling due to steel failures. Sandvik, to maintain this never-varying drill steel quality, control every phase of production—from the mining of iron ore, processing of wolfram ore, to the final tungsten-carbide-tipped steels used throughout the world wherever Atlas Copco drills are in action.

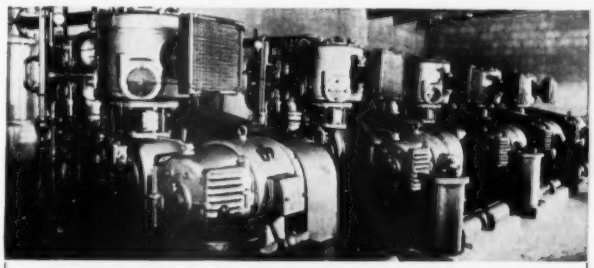
Drilling Advisory Service

Atlas Copco possess their own Project Department, whose job is to plan drilling operations and to advise on mining and tunnelling techniques. Their expert services are at the disposal of contractors and mining engineers without obligation.

The Atlas Copco Group puts compressed air to work for the world. It is the largest group of companies specializing solely in the development and manufacture of compressed air equipment. It embraces Atlas Copco companies or agents manufacturing or selling and servicing Atlas Copco equipment in ninety countries

85% of all rock drills at work on Italian power projects are Atlas Copco machines. Nearly half the steels, Sandvik Coromants. Here are some in action on a 10-mile tunnel for the Avisio project north of Trento. The drills were powered by several Atlas Copco AR compressors. Contractors: Ing. S. Quadrio Curzio.

An Atlas Copco LM 100 mine loader mucking-out on an Italian tunnelling scheme. Contractors: Geom. P. Tabacchi.



Five Atlas Copco AR 3 compressors installed on the site of big excavation operations in Sardinia. Contractors: SOGENE.

throughout the world. For further information about the equipment featured please contact your nearest Atlas Copco Company or Agent. There are Atlas Copco companies in Wembley (England); Paris; Rotterdam; Milan; Brussels; Copenhagen; Oslo; Stockholm; Essen; Madrid; Istanbul; Nicosia (Cyprus); Casablanca; Benoni (Transvaal S.A.); Ndola (N. Rhodesia) or Belmont (S. Rhodesia); Montreal; Paterson N.J. and San Carlos Cal. (U.S.A.); Torreon (Mexico); Auburn (N.S.W. Australia); Wellington; Rio de Janeiro; Santiago de Chile; Lima. If you have difficulty in contacting your local Atlas Copco organization please write to Atlas Copco AB, Stockholm 1, Sweden.

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FOR 275 K.V. SWITCHGEAR

This post insulator was designed and manufactured by Bullers Limited to the requirements of the British Electricity Authorities specification for 275 K.V. Switchgear.

BULLERS LIMITED design and manufacture both porcelain and metal parts in their own works.

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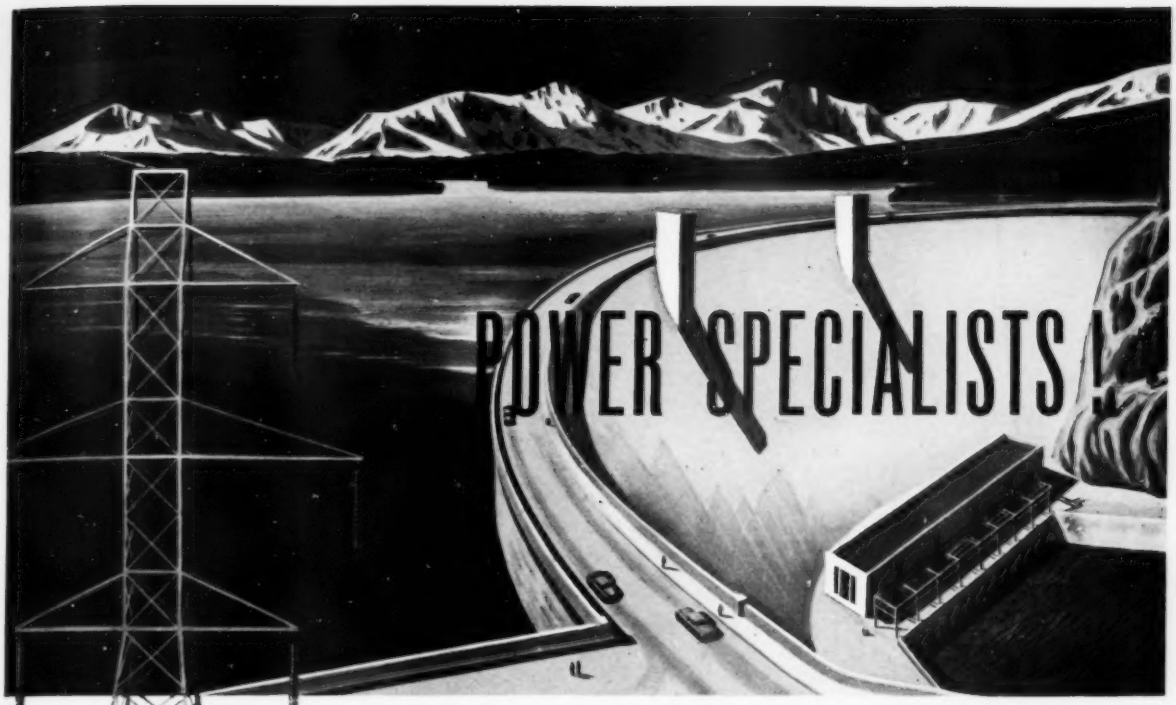
Height of post 116"
Cantilever strength 2,000 lb.
Dry withstand test 580 K.V.
Wet withstand test 520 K.V.



Kuljian has designed, engineered, and supervised construction of power plants the world over... with total electric generating capacity exceeding

2,000,000 KILOWATTS!

VAST power projects throughout the world—more than seventy in all—attest to The Kuljian Corporation's reputation as specialists in hydro-electric, steam, and diesel power plant design and construction. These plants represent a total generating capacity of over 2,000,000 kilowatts... a total investment of over half a billion dollars.

Behind every Kuljian project lie the combined skills and experience of a complete staff of internationally recognized experts in every phase of water resource development. No matter where *your* next project might be, The Kuljian Corporation is fully prepared to undertake efficiently all phases of design, engineering, and construction supervision to help bring about the quick, economical solution to your specific problem.

We invite your inquiry for detailed information.

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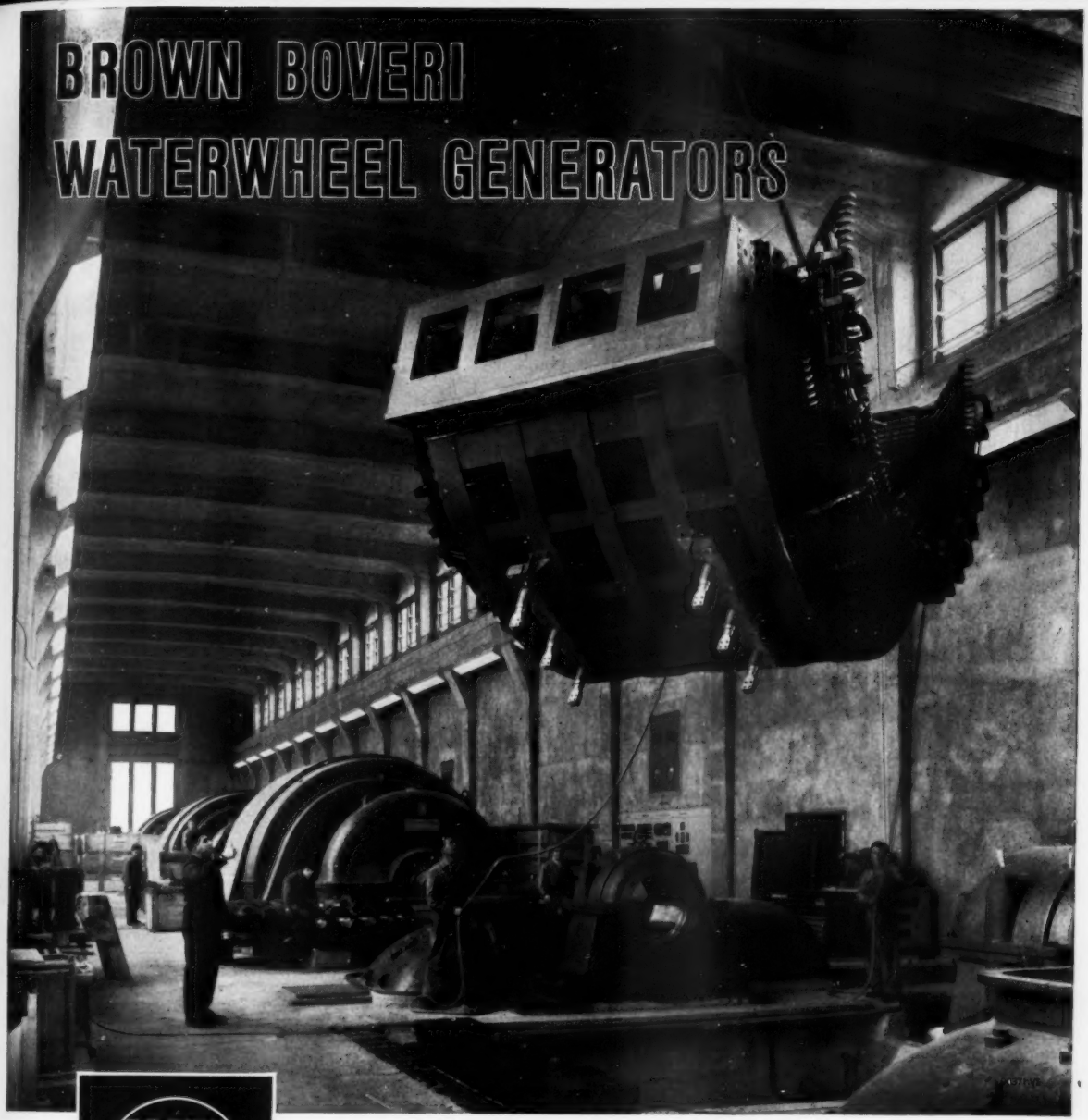
BROWN BOVERI WATERWHEEL GENERATORS



BROWN BOVERI

The fourth generator being erected in the Riddes Power Station, owned by the Forces Motrices de Mauvoisin S.A., Sion. So far, this is the largest hydro-electric power station (total generating capacity 335 MVA) in Switzerland.

Some large waterwheel generators at present under construction or being installed:

3 x 50	MVA	600 rev/min	(Mexico)
3 x 52·5	,,	428 ,,	(Switzerland)
2 x 53·3	,,	500 ,,	(Switzerland)
3 x 60*	,,	750 ,,	(Switzerland)
5 x 67	,,	500 ,,	(Switzerland)
1 x 60	,,	600 ,,	(Portugal)
1 x 75	,,	428 ,,	(Norway)
4 x 80	,,	333 ,,	(Switzerland)

*The largest in the world running at this speed.

BROWN, BOVERI & CO., LTD., BADEN (SWITZERLAND)

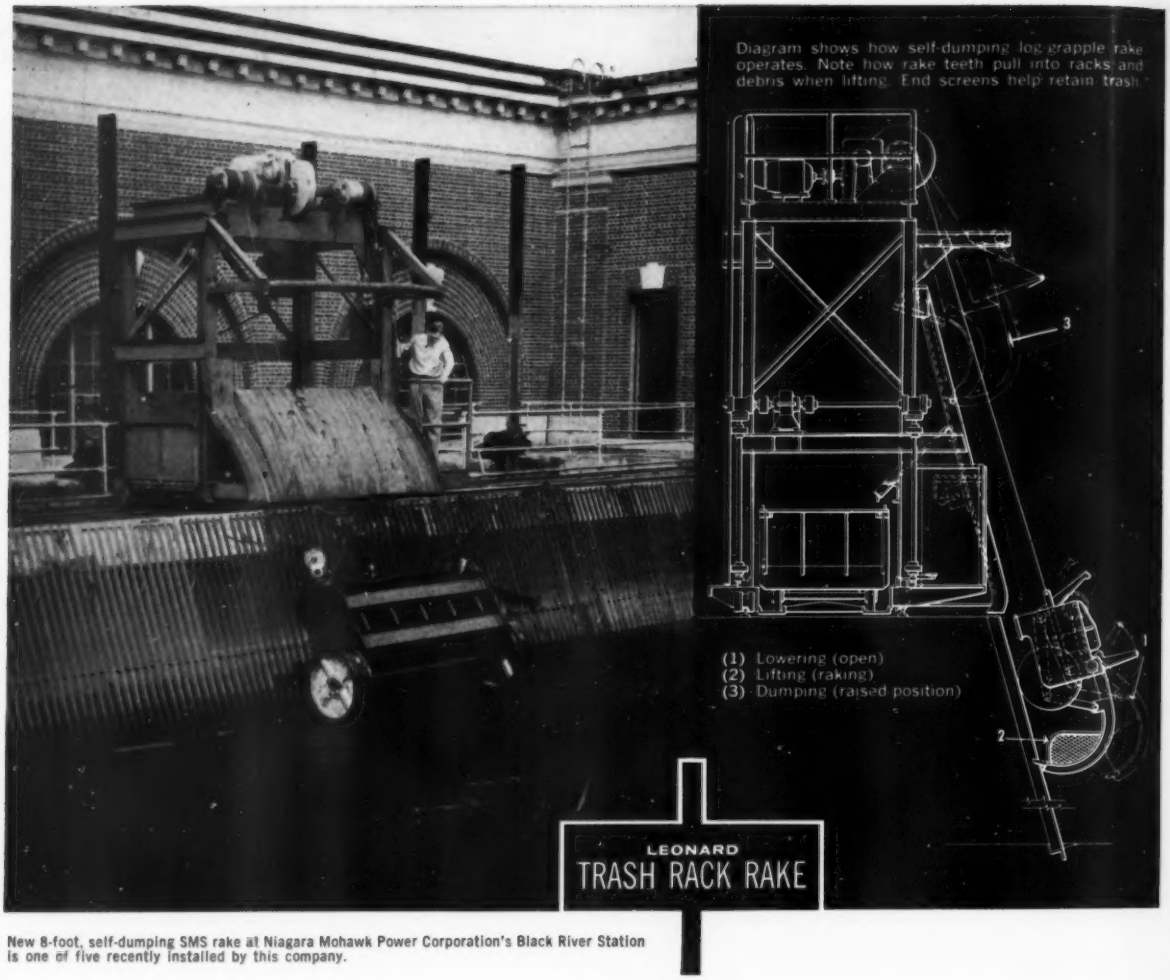


Diagram shows how self-dumping log-grapple rake operates. Note how rake teeth pull into racks and debris when lifting. End screens help retain trash.
(1) Lowering (open)
(2) Lifting (raking)
(3) Dumping (raised position)
1
2
3
LEONARD
TRASH RACK RAKE

New 8-foot, self-dumping SMS rake at Niagara Mohawk Power Corporation's Black River Station is one of five recently installed by this company.

Two New Self-Dumping SMS Trash Rake Designs CUT CLEANING TIME AND LABOR

Now SMS offers you two improved Leonard trash rack rakes, both regular and log-grapple types. These self-dumping rake designs make operation easier and quicker, permit you to clean a greater area faster. Both new rake types are now available as additions to the SMS line of standard rake designs.

SMS Leonard rakes operate directly on trash rack bars . . . ride down over stubborn obstructions and work them loose. Such freedom of movement assures fast, easy cleaning. Initial costs are low because the width of SMS rakes can be kept to the minimum required for handling for trash and the expense of guides attached to racks, or embedded in piers is eliminated. These rakes are of simple and rugged construction, designed for outdoor service and require minimum maintenance.

To get full information on Leonard trash rakes, or on other SMS accessories and hydraulic turbines, write to S. Morgan Smith Co., York, Penna. For Leonard rakes, request Bulletin 158.

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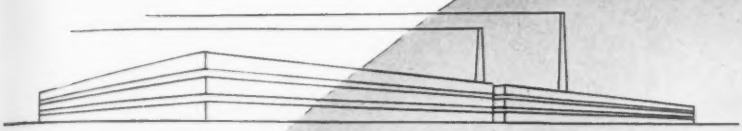
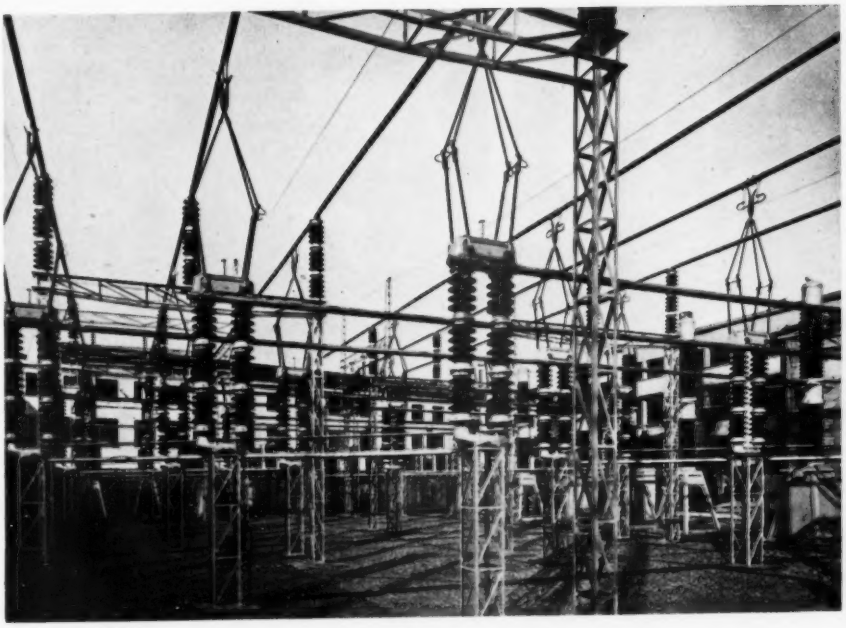
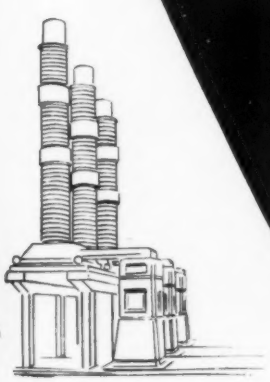




150 kV 600 Amps pantograph isolators installed at an Italian plant.



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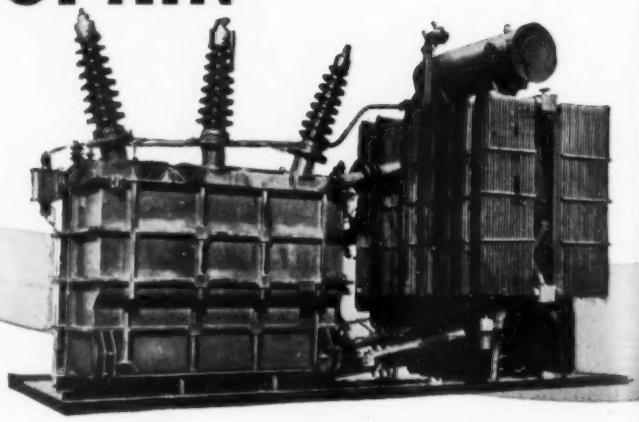
Three 16,000 kVA 6.6/138 kV Transformers at the Saltos del Sil Power Authority. The transformers were specially constructed to meet site requirements.

G.E.C.

TRANSFORMERS IN SPAIN



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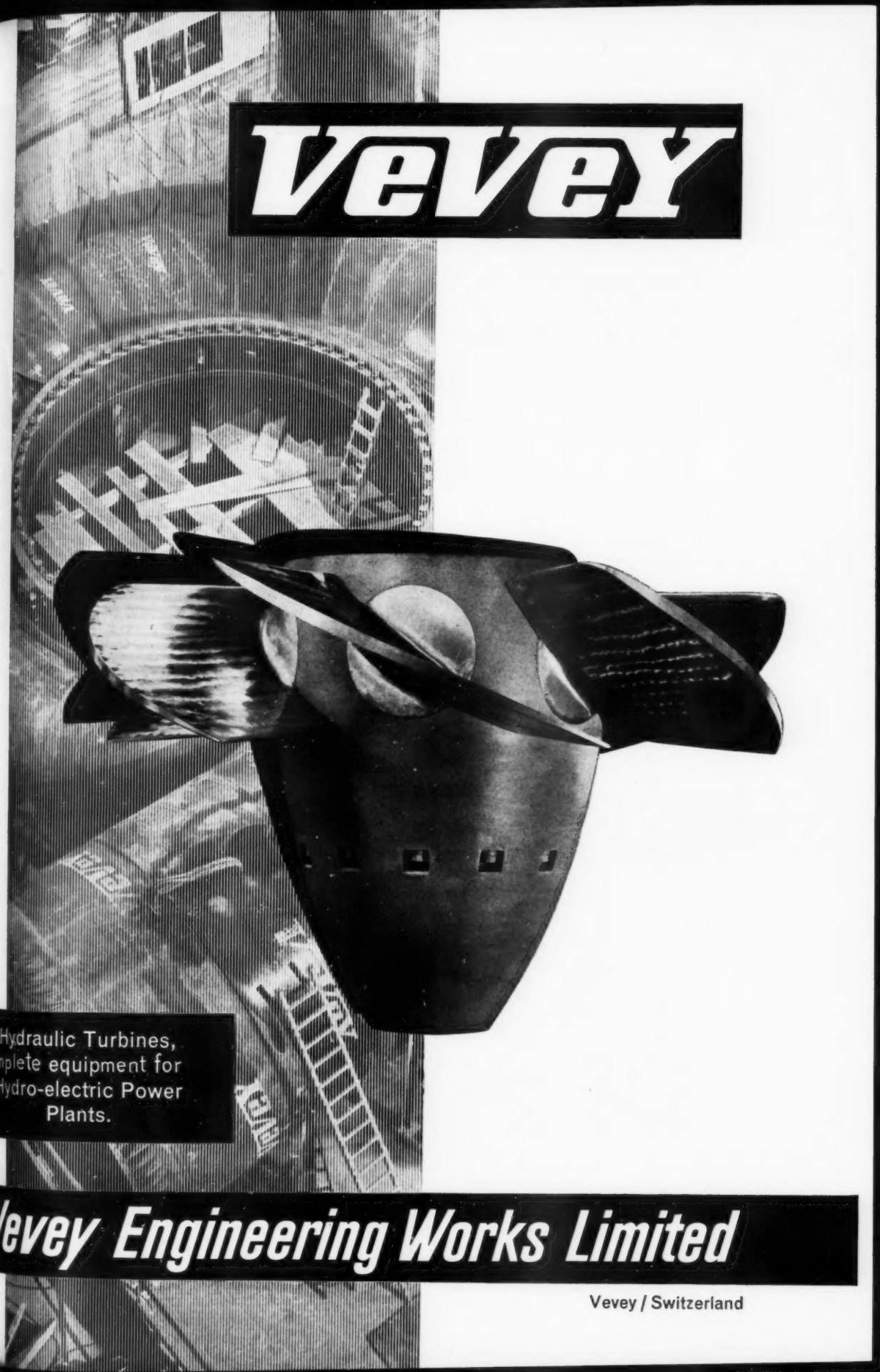
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Vevey Engineering Works Limited
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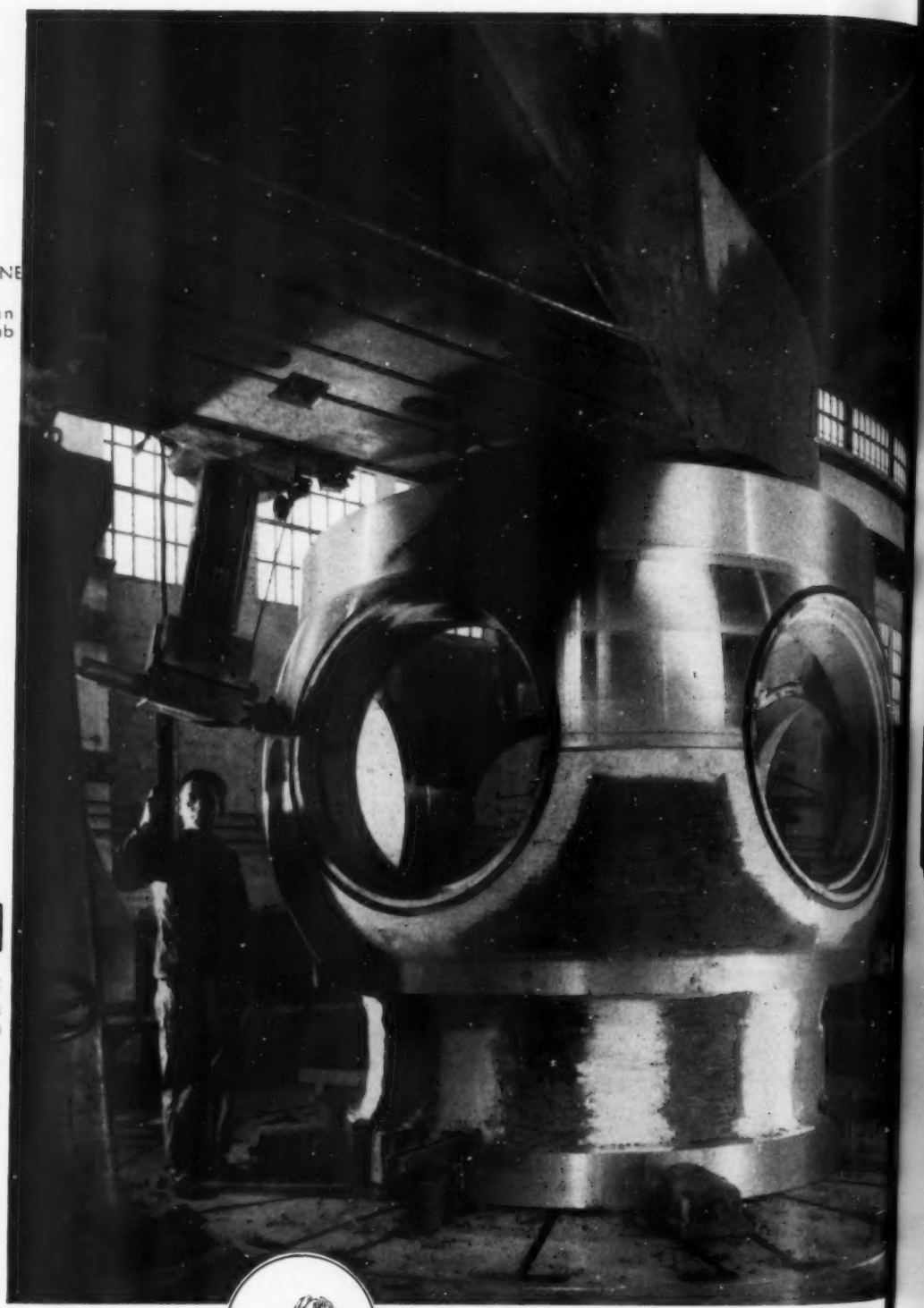

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Have established a leadership

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BIG JOB, SMALL WRENCH

From a reservoir served by the Nictaux River, 100 miles southwest of Halifax, water now flows via canal and wood stave pipe to this 3312′ Dresser-Coupled steel penstock.

The lighter weight, high-strength steel pipe was delivered to the job with Dresser Coupling middle rings and followers already in place. It was a simple matter to swing the long pipe lengths into the ditch. Then workmen put in the bolts and tightened the end nuts. *A wrench was the only joining tool required.*

That's how it is on all Dresser-Coupled jobs. No expensive skills or equipment are needed. Work can proceed in any weather at an average of only two man-minutes per bolt. And there's no need for exact pipe fitting or alignment. The resilient rubber gasket in every Dresser Coupling absorbs line stresses, strains and movement . . . permits expansion and contraction . . . keeps joints bottle-tight and trouble-free for life!

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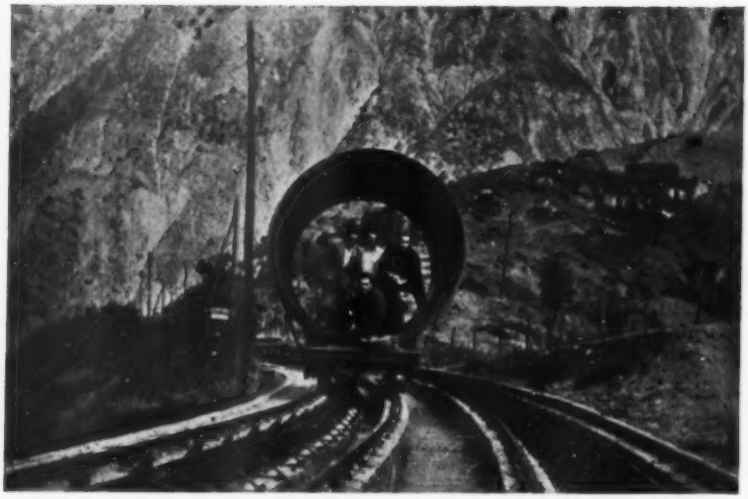

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OF ERECTION

Head—752 metres
Diameter—2·50-2·20-2·00 metres

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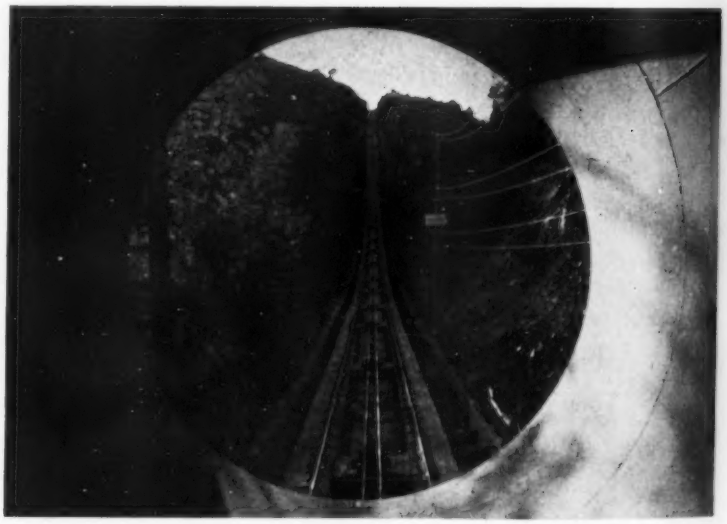

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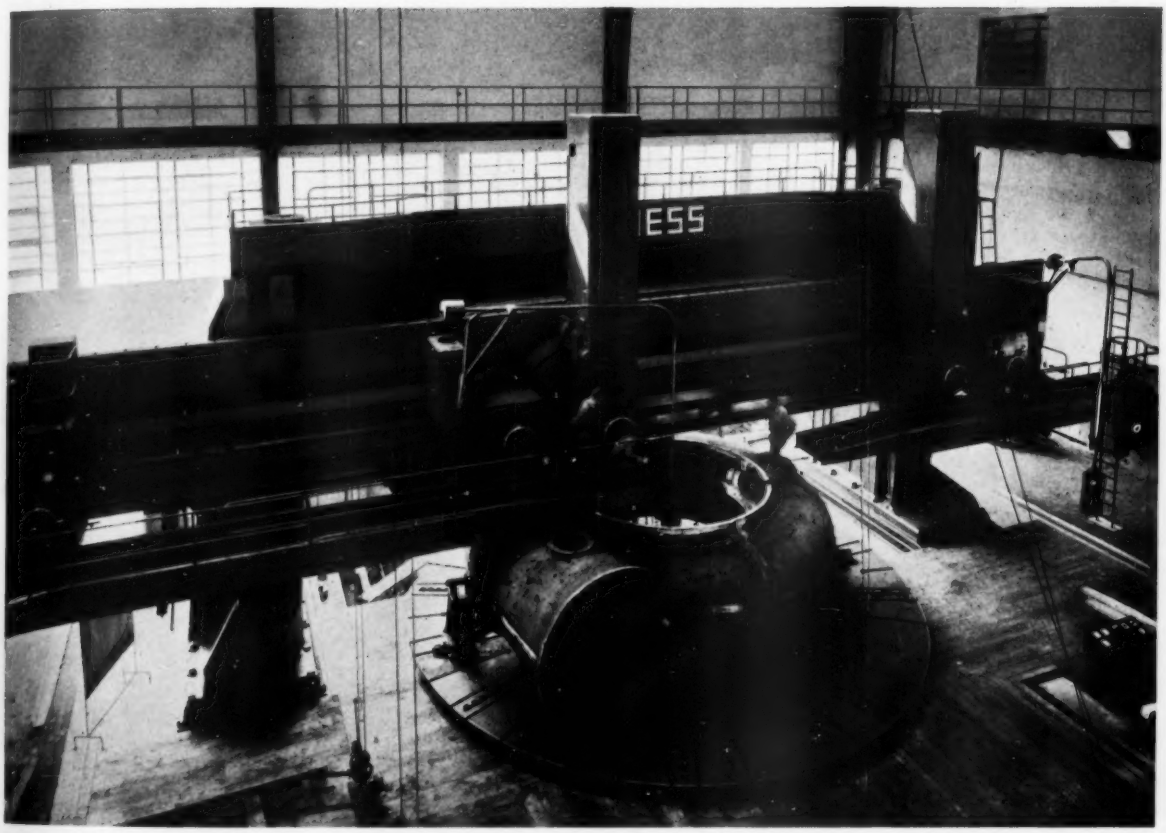

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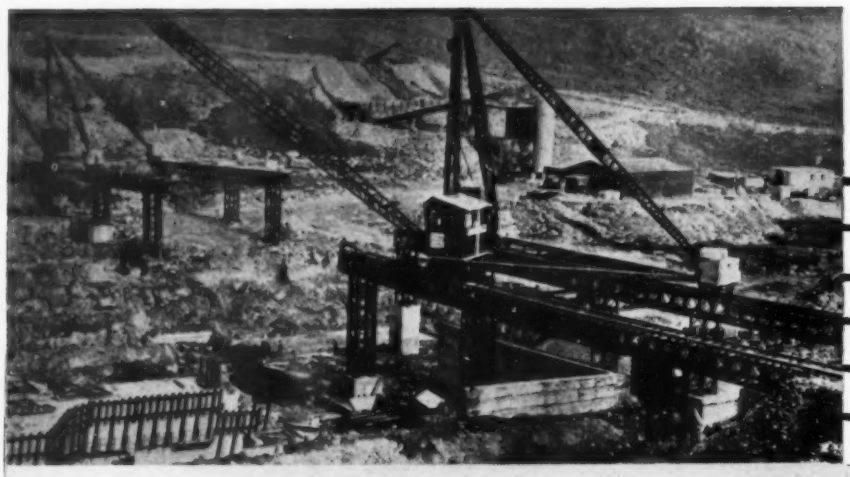

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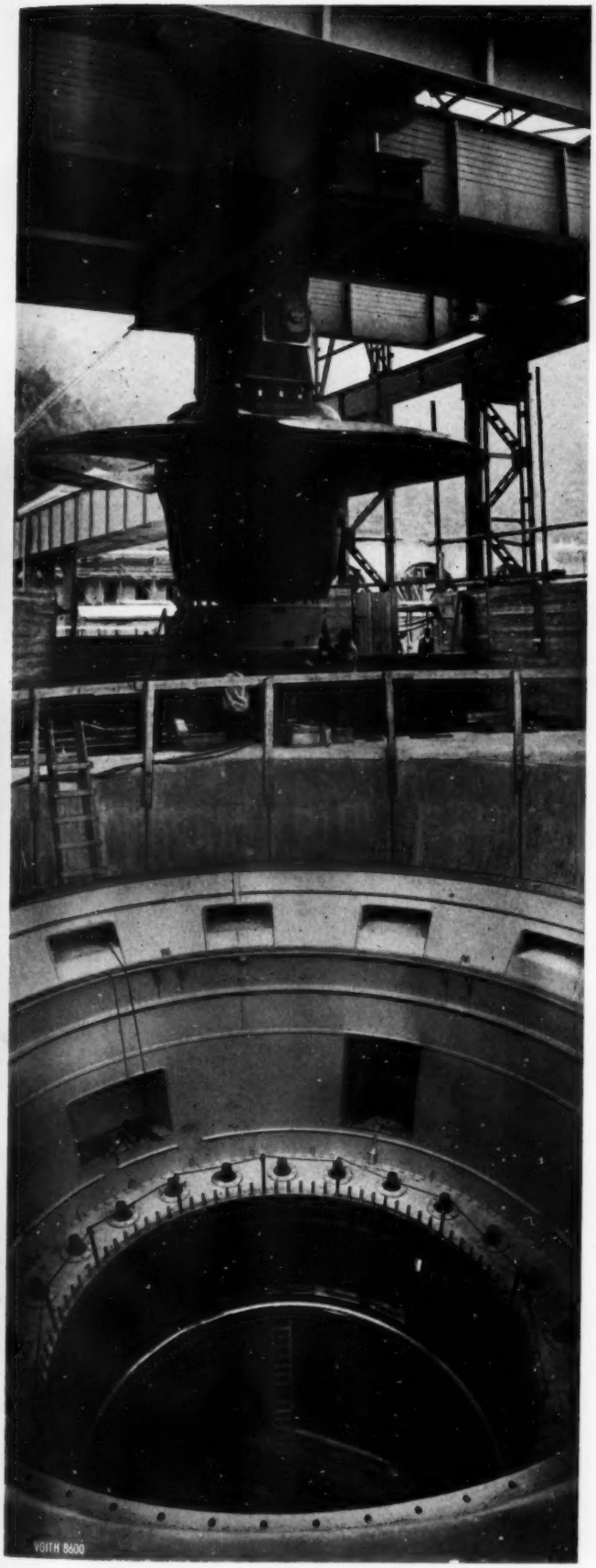

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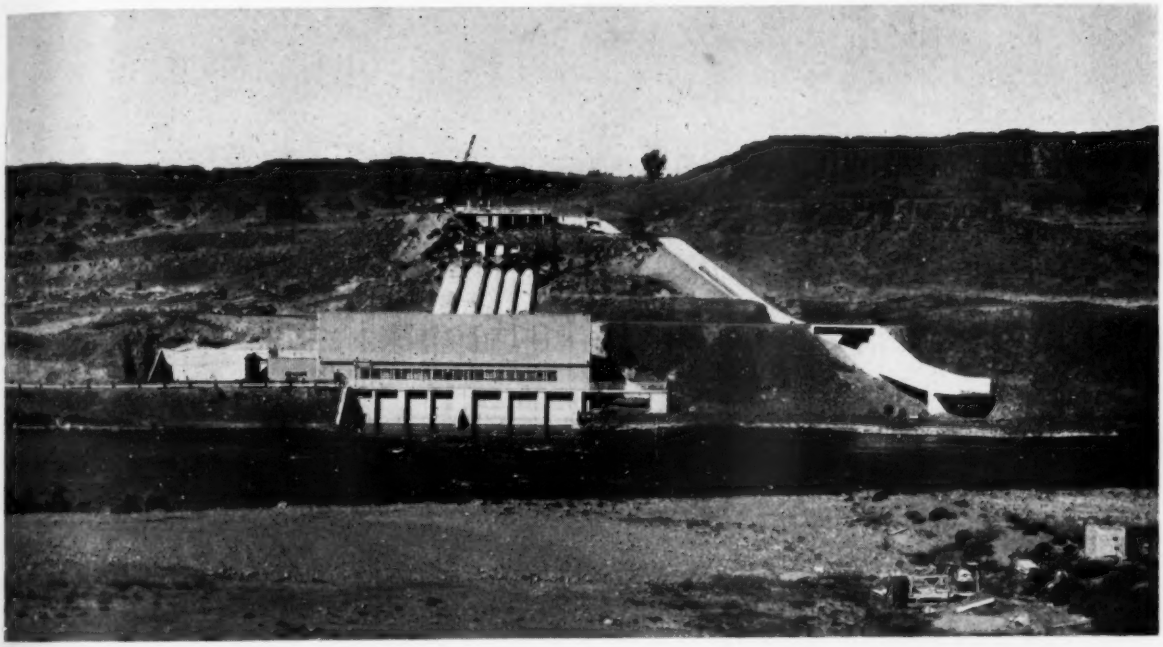

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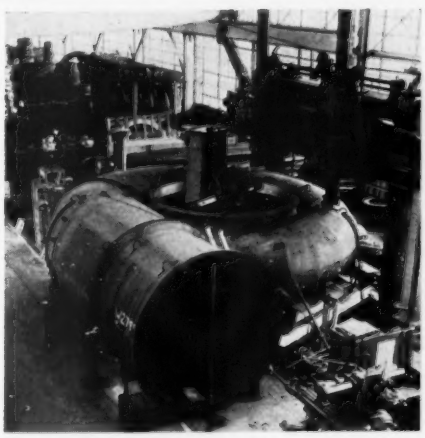

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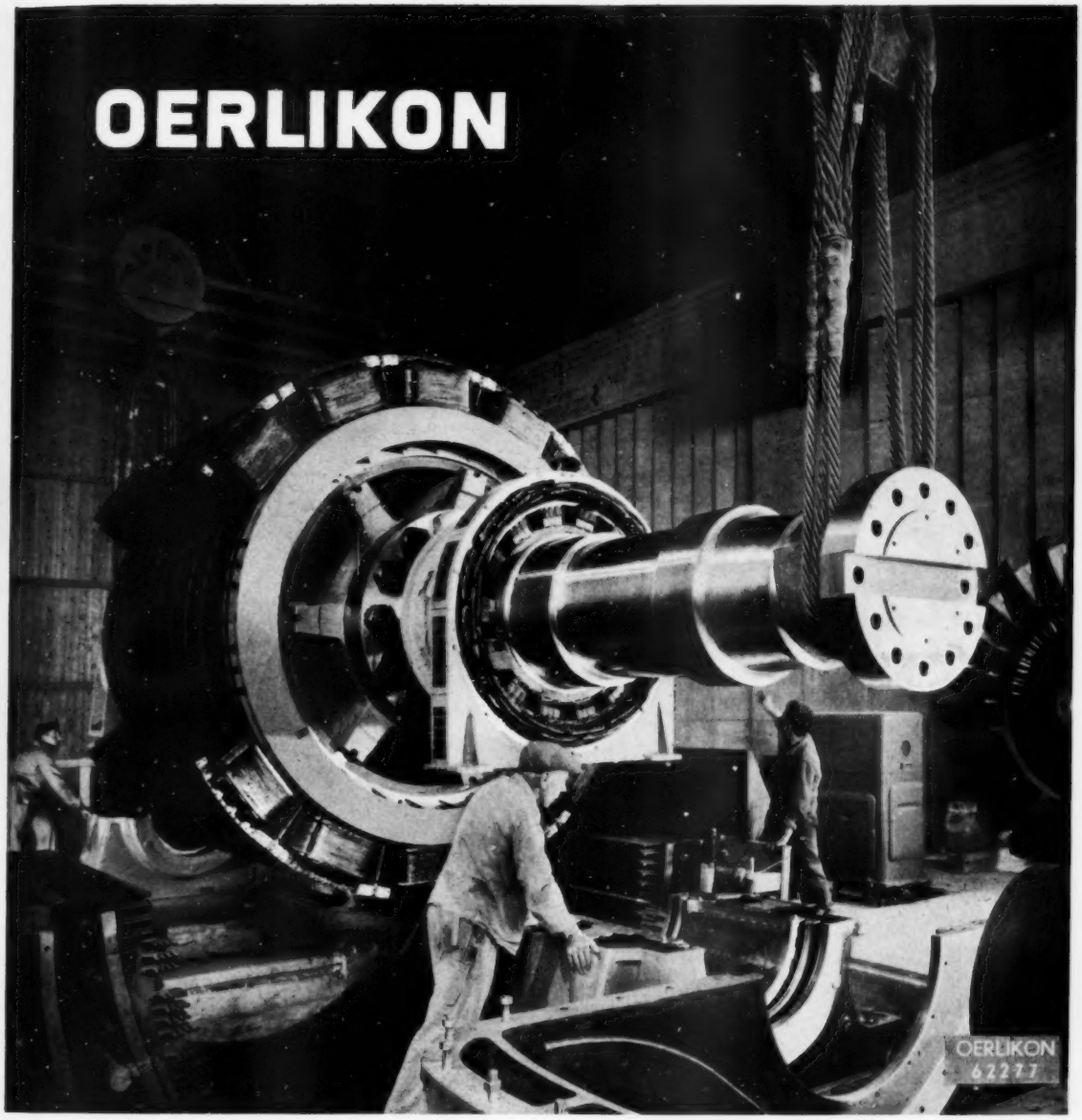

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The rotor of a 60 MVA alternator taking a hairpin bend on the mountain road from Le Châble to Fionnay.

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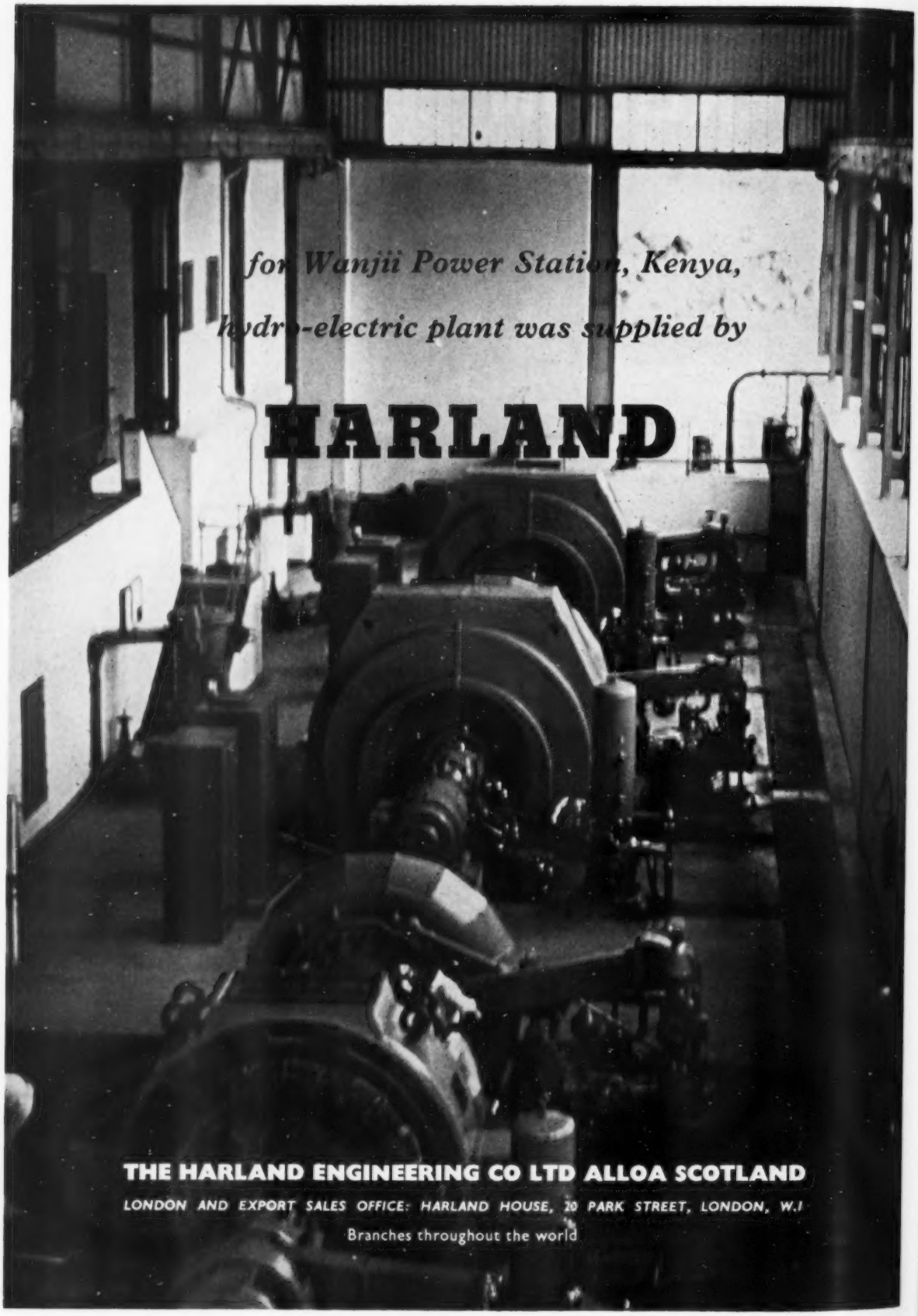
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Transmission Costs

IN recent years the economic pressure on hydro-electric development has steadily increased. New schemes must now satisfy cost criteria which, with the continuous rise in the price of every sort of civil engineering work and raw material, become more and more onerous.

The cost of the transmission line needed to link up remote water power sites to the centres of industry often amounts to an appreciable proportion of the whole project. With so many of the sites near industrial regions already harnessed, the transmission cost of new schemes becomes proportionately higher and this reason alone—if there were not others—is sufficient to cause intensified interest to be taken in reducing the capital cost of transmission.

Two lines of thought may be detected in engineering circles concerned with this problem. First, there is the suggestion, made at the CIGRE conference in 1956, that transmission line specifications are, in general, too conservative, and that reduced factors of safety could well be considered. This applies both to the electrical and the mechanical aspects of design. As pointers towards constructive thinking in this direction, mention may be made of the fact (already recorded in WATER POWER) that Swedish engineers at CIGRE consider much of their existing 400 kV equipment to be capable of being converted to operate a 500 kV with relatively little expense or technical difficulty; and from America there came the suggestion that instead of increasing the voltage of a given transmission route to accommodate additional power transfers, it might well be possible to modify existing lines, at any rate up to 330 kV, to provide greater current carrying capacity. In many countries, the use of series capacitors is either adopted or under consideration to increase the power load of an existing transmission system. Considerable research work is being undertaken in an increasing number of countries into the question of using direct current, at high voltage, for reducing transmission costs when long distances are involved.

The second trend which may well lead to a reduction in transmission costs is that of seeking for new methods of crossing obstacles hitherto regarded as insuperable. This trend itself may be considered under two headings. First, there is an increasing interest in the practicability of traversing mountain gorges or straits or fiords which hitherto have been considered as forming unassailable barriers to transmision engineers. There are at the moment four "long spans" which excite their interest. In Canada, the Kootenay line enables current to be carried across a span of 10,656 ft., or approximately 2 miles, while the famous crossing of the Messina Straits, to couple Sicily with the mainland of Italy, has needed the successful completion of a 3-phase overhead-line span of no less than 16,500 ft., or about 3 miles. In Norway, an even longer span, crossing the fiord separting Rabnaberg and Fatlaberg, has recently been commissioned, and overtops the Messina crossing by 400 ft., thus constituting the longest transmission span in the world. In Great Britain a 275 kV span crossing the rivers Severn and Wye is under construction, and will require a span of 2¼ miles.

These four long spans are all very different in regard to the type of conductor employed, the mechanical conditions under which the conductors operate, the overall design of the terminal equipment, and the designs adopted for the method of tensioning. From these notable examples it is likely that transmission engineers will learn a great deal that will enable them to contemplate transmission links over shorter routes than have hitherto been considered feasible, and this will also be of help in harnessing remoter water-power sites. In addition, it may well happen that the lessons learned from the long spans can usefully be applied to the design of normal transmission lines, so enabling fewer supports to be employed per unit length of run, with a consequent reduction in capital costs.

The second aspect of this trend towards overcoming transmission obstacles relates to the use of high-voltage direct current on submarine cables. The suc-

cessful commissioning of the Gotland Scheme in 1954, and its subsequent untroubled operational record, has already helped the British and French electricity authorities to decide on direct current for the cross-Channel cable, to be completed by 1960. This cable, about 25 miles in length, could, of course, have been operated on alternating current, although the losses would have been considerable. But it has, from the d.c. point of view, the very great advantage of allowing the British and French networks to operate at differing frequencies. Hydro-electric engineers are fully conscious of the desirability of allowing certain isolated hydro-electric stations to operate at a little above or a little below the standard frequency of the net work as a whole; and it is only by the use of direct current that this condition can relatively easily be achieved. This advantage of direct current is not restricted to submarine cables, however, as its application is universal. Had this stretch of water been 40 miles across or more, direct current would have been the only transmission method available as with a.c. the charging current would become prohibitive in value.

A reconsideration of the present very high safety factors applied to the design of extra-high-voltage transmission lines would thus seem to be due, in the majority of highly industrialised countries, in the light of the experience gained in "long span" techniques and in the use of direct current. By applying these and other means the proportion of the capital cost of harnessing a remote hydro-electric scheme may well be materially reduced.

Priest Rapids Contracts

THE award of a 92 million dollar contract to an American construction firm has brought The English Electric Company sub-contracts for hydro-electric machinery and associated equipment worth approximately 24 million dollars. The 12 million dollar order recently announced by the Grant County Commissioners covering water turbines formed part of this contract.

The main contract is for the construction of a new dam and power house at Priest Rapids on the Columbia River, and was awarded by Grant County Public Utility District No. 2 of Ephrata, Washington State, to the Merritt-Chapman & Scott Corporation, of New York. The Merritt-Chapman & Scott bid included English Electric water turbines, generators and transformers and a contract for this equipment, valued at approximately 24 million dollars, has accordingly been awarded to The English Electric Export and Trading Company.

The Priest Rapids site is downstream from Grand Coulee, Chief Joseph and Rock Island Dams, but upstream of McNary Dam and immediately above the confluence of the Snake River with the Columbia River. The plant to be installed by English Electric will comprise eight 114,000 h.p. water turbines and eight generators, each having an output of 83,000 kVA at 85·7 r.p.m. The output from each pair of generators will feed into a step-up transformer; five transformers (one being a spare) will be supplied by English Electric, each having an output of 183,000 kVA. They will raise the generating voltage of 13,200 volts to 230,000 volts for transmission to various consuming centres.

The Grant County Public Utility District No. 2 is governed by three commissioners, Messrs. F. William Arlt, William Schempp and George Schuster, and their technical operations are under the control of Mr. Glenn Smothers, as general manager. The whole project is under the technical supervision of the Harza Engineering Company, of Chicago, Illinois, whose services have been retained by Grant County P.U.D. as consultants.

Swedish Developments

THE Letten hydro-electric power and pumping station, owned by the Uddenholm Company and situated on a tributary of the Klaralven River in the province of Varmland, has now been put into service, the first unit in February and the second in June this year. The installed capacity is 36,000 kW. Each 18,000 kW unit comprises a horizontal Francis turbine, generator and pump, the generator working as a motor when pumping 8·5 cu. m. per sec. against the 190 m. head. The storage reservoir has a capacity of 176 million cu. m.

More recently, on September 2, the first of two units of the 124,000 kW Lasele power station was put into operation. This plant, belonging to the State Power Board, was described in WATER POWER, August 1955. The second unit is scheduled to be started in December this year.

Also in September the first 30,000 kW unit of the Edensforsen plant was put into operation. The power station is situated on the Angerman River and belongs to the Graningeverken Company. A second unit is being installed and will be ready for operation before the end of the year. The station will have a total capacity of 60,000 kW and the average annual generation will amount to 280 million kWh.

Developments in Pakistan

TWO British experts, Dr. Kurt Billig and Mr. Harry R. Rodgers, have accepted appointments from the United Nations Technical Assistance Administration to advise on the water resources of Pakistan. The appointments, which have been made at the request of the Government of Pakistan, are part of the programme of the United Nations and the Specialised Agencies in assisting less-developed countries in utilising natural resources, in solving development problems and in raising living standards. Both appointments are for one year. Mr. Rodgers is expected to take up his duties about October 30, and Dr. Billig about November 15.

As an adviser on dam construction, Dr. Billig will work with the Chief Engineer of the Gudu Barrage Project in planning the general organisation of the major constructional work. He will also assist in training local personnel who will be engaged in this work. Mr. Rodgers will advise the Chief Engineer of the Gudu Project on the operation, maintenance, overhaul and repair of the constructional equipment in use.

Before undertaking this appointment, Dr. Billig was from 1952-1955 Director of the Central Building Research Institute of India, New Delhi. From 1950 to 1952 he was Professor of Civil Engineering at the Uni-

versity of Hong Kong. Earlier he was Chief Engineer and Partner of Messrs. Waller and Billig, Consulting Engineers of London. Dr. Billig holds degrees from the University of Vienna and is a member, *inter alia*, of the Institute of Civil Engineers, the Institution of Structural Engineers, and the American Society of Engineers.

Mr. Rodgers served from 1951 to 1955 as the Mechanical Supervisor for the Cameroon Development Corporation where he was responsible for all maintenance work.

Further Kariba Contracts Awarded

THE Federal Power Board of Rhodesia have now announced the award of two further contracts for additional electrical equipment for the Kariba hydro-electric scheme. The first of these has been secured by the British Thomson-Houston Export Co. Ltd. and is for the supply and installation of the 330 kV switchgear for the main station and for part of the transmission system equipment, the value being rather over £2,100,000. A. Reyrolle & Co. Ltd., of Hebburn, have secured the second contract, also for the supply and installation of switchgear, which has a value of just over £36,000.

Costains are now completing African bachelor units at the rate of 250 rooms a month and houses for Europeans at the rate of 20 a month. Some 250 houses will be required for the European township and in addition there will be the usual camp amenities such as a canteen, a swimming pool, hospital, church, school, post office, bank, theatre, recreation centre, beer hall and a police station—if we are correct as classifying a police station (complete with cells) as an amenity.

Hydro-Electric Engineers Visit U.S.S.R.

A DELEGATION of six British experts in hydro-electric engineering left London by air for Moscow last month for a two weeks' visit to the U.S.S.R. to study hydro-electric projects. The visit was arranged by the Institutions of Civil, Mechanical and Electrical Engineers and the Soviet Relations Committee of the British Council at the invitation of the Soviet authorities.

The group was led by Sir John Hacking, M.I.E.E., consultant to Messrs. Merz and McLellan, consulting engineers, Westminster. Other members were: Mr. A. A. Fulton, F.R.S.E., B.Sc., M.I.C.E., member of the Council of the Institution of Civil Engineers, general manager of the North of Scotland Hydro-Electric Board, Edinburgh; Dr. S. P. Hutton, Ph.D., M.Eng., A.M.I.C.E., A.M.I.Mech.E., head of the Fluid Mechanics Division, D.S.I.R., Mechanical Engineering Research Laboratory, E. Kilbride, Glasgow; Dr. W. MacGregor, D.Sc., A.M.I.C.E., a director of Messrs. George Wimpey and Company; Mr. R. W. Mountain, B.Sc., M.I.C.E., M.I.E.E., a partner in Messrs. Kennedy and Donkin, consulting electrical engineers, Westminster; Mr. Harry West, M.I.E.E., a director and chief electrical engineer of Metropolitan Vickers Electrical Company, Trafford Park, Manchester.

The delegation visited hydro-electric power stations at Dnieper, Kakhovka, Stalingrad, Sevansky Kaskad and Khramsky. Other items in the programme included visits to research institutes concerned with hydro-electric power in Moscow, Stalingrad, and Erevan and a factory in Leningrad producing hydro-turbines.

A return visit by a group of Soviet engineers to the United Kingdom will probably take place early next summer.

Progress on the Rihand Project

THE Rs. 45·26 crore Rihand dam project which will have an installed capacity of 285 MW is steadily progressing at Dudhi, in the south Mirzapur district in U.P. The subcommittee of the Board recommended that the contract for the power-house installations costing Rs. 2·75 crores should be given to the English Electric Co. Ltd., and this recommendation has been approved by the State Cabinet. The Rihand scheme is a multi-purpose project involving the construction of a concrete gravity dam 296 ft. high and a power house about 28 miles from the confluence of the rivers Rihand and Sone. Out of the total estimated outlay, Rs. 30 crores will be spent on the construction of the dam and the remainder will go towards the erection of the generating plant, transmission lines and other installations. An additional pick-up dam is contemplated to be built at a site about 30 miles down the Rihand, which is expected to generate about 75 MW. Reports available of the progress with the project are satisfactory. Final designs for the dam have been completed, and a bridge across the river was opened to traffic in June. Other principal works now under way are a bridge across the Sone river 3,300 ft. long and comprising 22 spans of 150 ft. each, a 50-mile road connecting the dam site with Robertsgunge and another 3½-mile road link. A railway siding has already been completed.

Upper Peribonka Scheme to Proceed

THE Aluminum Company of Canada, Limited (Alcan) have announced that a group of general contractors has been selected to carry out the construction of a new million h.p. hydro-electric development at Chute-des-Passes on the Upper Peribonka river. The contractors forming this group are Perini Quebec, Inc., sponsor, McNamara Quebec Ltd., and Quemont Construction Ltd. H. G. Acres & Co., Limited, who designed the Bersimis power project, have also been appointed as engineers for this scheme.

Alcan has leased the right to develop the Upper Peribonka from the government of the Province of Quebec and has been carrying out engineering and geological studies to determine the most economic design for this new development. It is now expected that first power from the new powerhouse will be generated in about three years, and included in the programme is the construction of 120,000 tons of additional aluminum smelting capacity in the Saguenay.

The new power facilities will be constructed a few miles below the existing storage dam at Passe Dangereuse which creates one of Alcan's main storage reservoirs on the Upper Peribonka river. An intake tunnel six miles long will be constructed from this reservoir to a point downstream where a gross head of 636 ft. is obtainable and where an underground

generating station will be installed. The water, after passing through the tunnel and power station, will be discharged into the Peribonka river to resume its normal flow into Lake St. John and the Saguenay River, passing, on its way, through Alcan's four downstream generating stations before reaching sea level. Additional generating capacity to the tune of one million h.p. will be installed and is expected to add 700,000 h.p. to the firm power obtained from the Saguenay power system as a whole.

Hume Weir Station, Australia

A NEW hydro-electric power station, located at the Hume Weir on the Murray River near Albury, New South Wales, is being constructed by The Electricity Commission of N.S.W. For this purpose the weir level is being raised from 104 ft. to 117·5 ft.

The output is to be shared equally between The Electricity Commission of N.S.W. and The State Electricity Commission of Victoria. Power generated for the N.S.W. Commission will be stepped up to 132,000 V for delivery to a transmission line linking Hume power station with neighbouring centres and thence to the N.S.W. interconnected system. The link with the Victorian Commission's system will be formed by a transmission line operating at 66,000 V.

The turbo-alternators are being installed which can operate either as generators or as synchronous condensers. The continuous maximum rating of each turbo-alternator at 95 ft. effective head will be 27,778 kVA (25,000 kW) and the quantity of water required per unit under conditions of maximum continuous rating will be 3,580 cusecs.

An unusual feature of the installation is that the usual butterfly valve in the penstock for isolating the turbine has been omitted in favour of a series of shutters around the eye of the spiral casing. These are Khatima shutters, first installed in an English Electric machine at Khatima, India.

British Guiana Proposal

IN connection with a proposed rural-electrification scheme in British Guiana, a British firm of consulting engineers, Messrs. Preece, Cardew & Rider, has submitted a report to the Crown Agents for Oversea Governments and Administrations as to the possibility of supplying the power for such a scheme from water resources. The topography of the country is such that the nearest economically developable site for a hydro-electric station is about 100 miles from the main population area, which is located along the coastal fringe. Nevertheless a site has been selected on the Demerara River, where a development of about 30 MW would seem to be possible by building a dam across the river. The report sets out the investigational work that would have to be put in hand, and an estimate of the cost of this work is given.

Channel Cable to be Laid

AFTER much investigational work it has been finally decided to lay a cable connecting the British C.E.A. electrical network with that of Electricité de France. The connection is expected to be in operation by 1960 and to cost £4 million. A joint committee set up by the two electricity authorities has reported the diversities of demand in the two countries to be sufficiently important to justify this cost and although the capacity of the cable will be only 120-150 MW—which seems very little in relation to the joint generating capacities—the exchange of this amount of power in times of peak demand will have considerable operational advantages, and will lead to substantial capital savings in providing new peak-load plant. For instance, in this country the cost of a power station of 120 to 150 MW capacity would be in the neighbourhood of £9-10 million, whereas the British share of the cable will only amount to £2 million.

The first proposal was to transmit 3-phase current at 132 MV, but the success of the direct-current linkage between Gotland and the Swedish mainland has decided the joint committee to recommend a similar cable operating at 200 kV with, of course, rectifying equipment at each end. This will enable the power to be transmitted in a single cable instead of the four (one as standby) that would have been necessary with alternating current. Besides being more economic, a single cable involves less risk to interruption from trawlers or ships anchoring in the Channel. Further advantages of the direct-current connection are that it will allow the two systems to control their frequencies independently of each other and to regulate the agreed load exchange with much greater precision than would be possible with alternating current.

Turbines for Swift Creek Plants

S. MORGAN SMITH COMPANY, of York, Pennsylvania, have been awarded a contract for five hydraulic turbine units valued in excess of three and a quarter million dollars by the Bechtel Corporation, who act as engineers and agent for the Pacific Power and Light Company and Cowlitz County Public Utility District. This order will form part of the equipment of two new plants located three miles apart on a tributary of the Lewis River in Washington.

The three 100,000 h.p. units for Swift Creek Plant No. 1 will operate at 180 revs. per min. under a net head of 350 ft. The contract calls for 11 ft. diameter spiral cases, fabricated of T-1 steel, which will be sectionalised for field welding of radial splits. The York firm will also design and manufacture three 13 ft. hydraulically operated butterfly valves for turbine inlet service at Swift Creek No. 1.

The application of T-1 steel is believed to be the second occasion on which this new alloy has been used for spiral cases. The first was in the cases made for the Brownlee plant on the Snake River in Idaho.

The downstream Swift Creek Plant No. 2 will have two 46,000 h.p. units operating at 128·6 revs. per min. under a 128 ft. head. The mild-steel spiral cases for this plant measure 16 ft. and will be completely field welded. These units will discharge into the forebay of the Yale development of the Pacific Power and Light Company, where two 70,000 h.p. turbines, built by the same makers several years ago, operate under a net effective head of 224 ft.

Delivery dates for the Swift Creek turbines begin in the late autumn of 1957 and will run until late spring of 1958. Telemetering from the Merwin Station will provide load control for both plants.

Tunnel Blasting at Harrsele

Ragnar Ahlström, Chief Engineer, Hjälta A.B. and Harrsele A.B., Stockholm, describes the procedure and gives performance figures, for the blasting of the discharge tunnel for the Harrsele Hydro-Electric Plant in the River Ume in Sweden

ONE of the most interesting tunnelling projects in Sweden is being carried out at Harrsele as part of a hydro-electric power plant being built on the Ume River. The dimensions of the discharge tunnel are particularly large, namely, length 3,400 m., height 18 m., width 15 m., and cross-sectional area 250 sq. m. The net volume of rock to be excavated amounts to 850,000 cu. m.

The Harrseleforsen and Fällforsen waterfalls on the Ume river are both being utilised in a single power plant located about 15 km. north-west of the Vännäs railway station. Principal data are:—

Total gross head	54·5	m.
Extension for a water discharge of	420	cu. m. per sec.
Power	190,000	kW
Energy production	955	million kWh

There is a regulating storage reservoir having a capacity of 1,390 million cu. m. at Storuman. The main works consist of:—

(1) A dam over the river at the neck of the Harrseleforsen fall, and appropriate intakes for three units

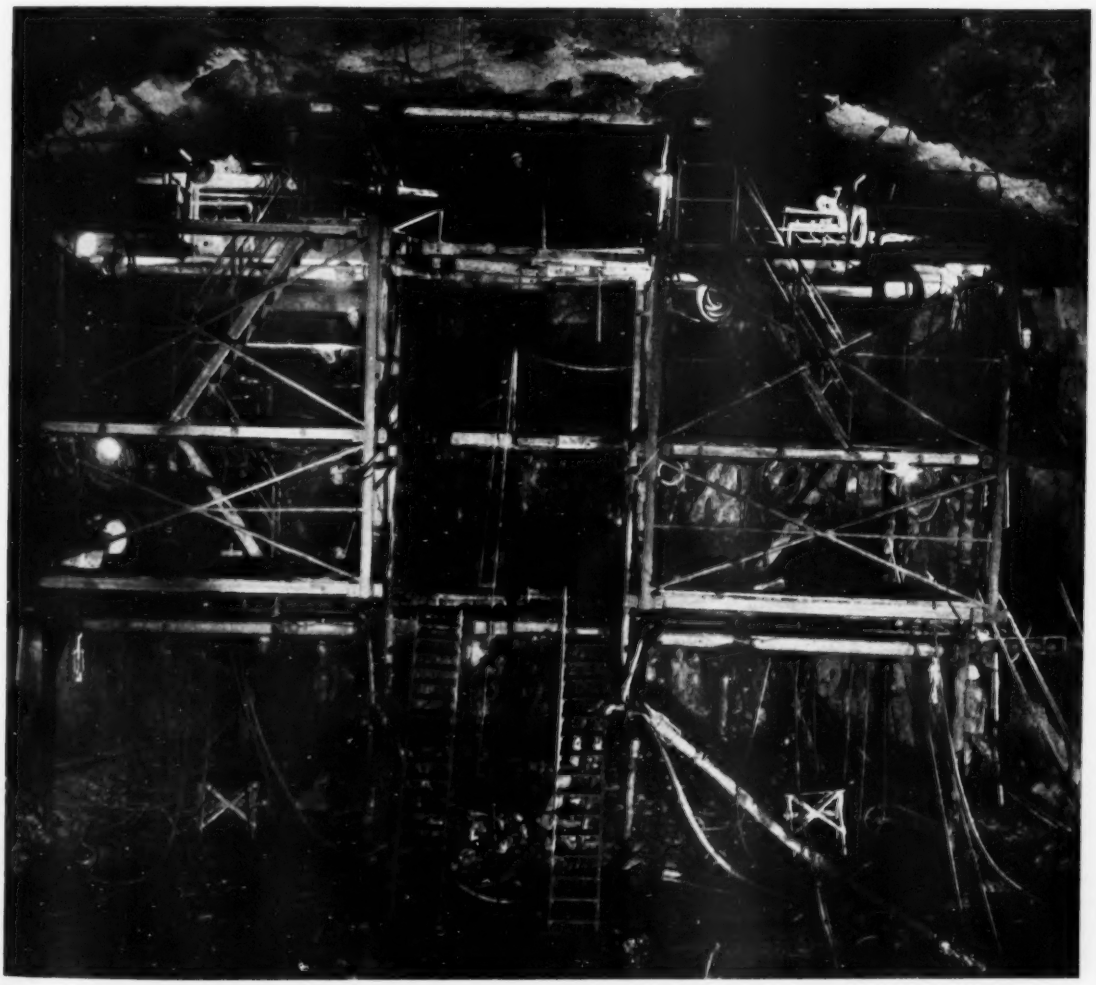

Fig. 1. Top heading, Harrsele, which has a cross-sectional area of 1,410 sq. ft. (130 sq. m.); after drilling, the jumbo is loaded on to two Euclid trucks and moved to safety

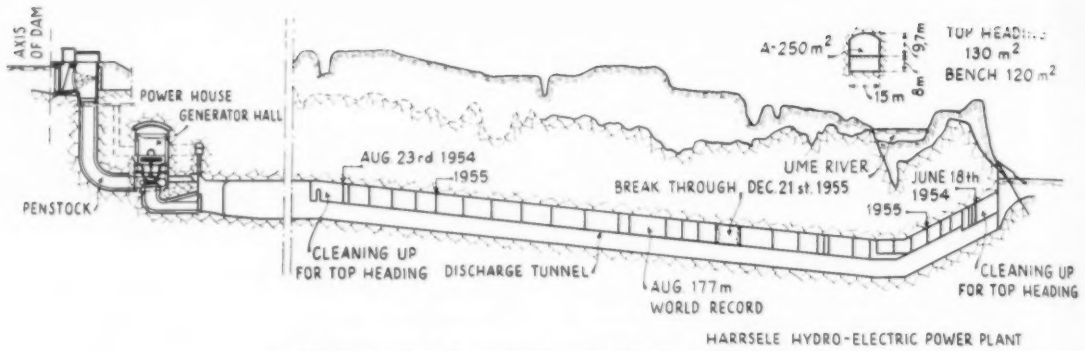

Fig. 2. Section through Harrsele discharge tunnel

on the left bank of the river, connected to the dam.

(2) A subterranean power station in which three power units will be installed, consisting of Francis type-turbines (KMW) each of 88,070 h.p., and generators (ASEA) each of 67,500 kW capacity.

(3) A discharge tunnel, which runs under the Ume river just upstream of the Fällforsen falls, on the left bank, and emerges into a short open cut downstream.

The hydro-electric power plant is owned by Harrsele AB, who are part-owners of three forestry companies—Mo och Domsjö AB, Nordmalings Ångsågs AB, Svenska Cellulosa AB—as well as Sydsvenska Kraftaktiebolaget. A/B Vattenbyggnadsbyrån, Stockholm, are the consulting engineers for the building work and the equipment.

The power plant is being constructed by the Company itself. The Site Manager is Mr. Jörgen Jörgensen, who was also concerned with the Hjälta tunnel project. Deputy Site Manager, Mr. Sten Wallin, who is responsible for the tunnelling work, compiled most of the tunnel data for this article. According to the current working schedule the first generator will be in operation for commercial purposes on September 1, 1957, with the other two coming into use during the first half of 1958.

The discharge tunnel is being driven in two stages. Using the full-face method, a top heading with a cross-sectional area of 130 sq. m., 9·7 m. high and 15 m. wide was driven with tunnel crews operating from each end. The break-through took place on December 21, 1955—three months ahead of schedule—and 18 months to the day after the first full-face charge was fired in the top heading at the downstream end of the tunnel. The best advance for the month was 585 ft. and is claimed as a world record for a tunnel of this size. Work is now in progress on the remaining bench which is 8 m. high and has an area of 120 sq. m.

The rock consists mainly of garnet gneiss. As usual, a considerable amount of preparatory work was required before full-scale driving operations could be started. The first round was fired on October 12, 1953, for a 450 m. long transportation tunnel having an area of 44 sq. m. The blasting of this tunnel, which has a gradient of 1 : 9 to 1 : 10, was completed on April 1, 1954.

The transportation tunnel in the downstream section was shorter, and full-face blasting began just before midsummer, 1954. On many occasions poor rock interrupted the work and in the beginning of October the area was reduced to 53 sq. m. The sections of poor rock which were periodically encountered, together with the consideration of possible risks inherent when driving under the river, contributed to the decision to retain this area of 53 sq. m. until the end of March, 1955. The river was passed without mishap and at that stage the crews had driven a 400 m. drift which was widened to full tunnel width, although not taken to the height of the 130 sq. m. top heading.

The following rates of advance and working results refer to the blasting of the upstream section of the top

TABLE I—MONTHLY ADVANCES IN TOP HEADING (130 SQ. M.); UPSTREAM SECTION

	Monthly advances	Number of rounds	Size of round	Number of missed rounds	Number of working days
1954	m.		m.		
Sept.	103·05	22	4·68	1	26
Oct.	112·65	21	5·36	2	26
Nov.	111·20	20	5·55	2	25
Dec. (1)	98·50	18	5·47	—	20
1955					
Jan. (2)	127·50	21	6·07	2	24
Feb.	136·50	20	6·83	2	24
March	151·80	24	6·33	—	27
April	144·90	20	7·25	—	23
May	159·20	21	7·58	—	23
June	164·10	21	7·81	—	24
July (3)	47·40	6	7·90	1	8
Aug.	177·00	22	8·05	2	27
Total and average	1.533·80 (4)	236 (5)	6·50	12 (5)	277 (5)

(1) Suspension of work between Christmas and the New Year. (2) Agreement was reached with tunnel crew about piecework rate on January 12. (3) Three weeks holiday. (4) Average monthly advance, including stoppages for Sundays and vacations = 128 m. (5) Only 12 missed rounds are included in the table, i.e., rounds lost because of poor rock or breakdown of machinery or equipment. For the rest, the difference between the number of working days and the number of rounds is due to the fact that on account of the current regulations governing working hours, not more than five rounds a week are fired.

heading, which, until September 6, 1955, was driven for more than a year with hardly any interruptions caused by poor rock. On that date however weak ground was struck and the even rhythm of the work was interrupted for nearly two months. The work was carried out continuously in three-shift operations.

TIME CYCLE—ONE ROUND FIRED EACH 24 HOURS

Drilling, charging and firing	hours	hours
Advance and withdrawal of jumbo	1·5	
Drilling, incl. setting-up	3·5	
Charging	1·5	
Ventilation	0·5	
Mucking of round and advance of excavator	0·5	
Pauses in work (meals)	0·5	
	—	8·0
		8·0
Loading and haulage of broken rock as well as post scaling		16·0
		24·0

PERSONNEL

Engineer in charge of section	1	
Senior foreman	1	
Shift foremen	3	
Transport foreman	1	
Foreman for repair workshop and electrical workshop	1	
Layer-out of drilling patterns	1	
Time recorder	1	
	—	9
Rock-blasting crew:		
Foreman	1	
Drillers	20	
Scalers	7	
Excavator operator	3	
	—	31
Excavator greaser	3	
After scalers	5	
Truck drivers	18	
Miscellaneous labour	12	
Carpenter	1	
Grinders for drill steel	2	
Rock - drill repairmen and compressor operators	3	
Shift repairman	1	
Shift electricians	3	
Mine car tippers	3	
Excavator repairmen	3	
Workshop workers	3	
Tractor drivers	3	
	—	59
Total men		99

During the period February up to and including June 1955, the average advance was 7·16 m. per round, and the net volume of rock excavated was 930 cu. m. The corresponding working time of the rock-blasting crew was divided as given in Table II:

TABLE II—WORKING TIME OF ROCK-BLASTING CREW

	hour/round	hour/cu. m.
Advance and withdrawal of jumbo	31·5	0·034
Drilling, including setting up	73·5	0·079
Charging, incl. setting up	31·5	0·034
Ventilation, mucking of round, pauses in work (meals)	31·5	0·034
Scaling	56·0	0·060
Loading	24·0	0·026
31 men × 8 hours	248·0	0·267
Addition for sundry extra work and overtime (average during the months February up to and including June, 1955	18·6	0·020
	266·6	0·287

Fig. 3. Mechanical scaling platforms which are used to promote both speed and safety in large Swedish tunnels

TOTAL WORKING TIME PER CU. M. OF ROCK (EXCLUDING REINFORCEMENT WORK) FOR THE COMPLETE LABOUR FORCE FEBRUARY UP TO AND INCLUDING JUNE 1955

	hours per cu. m.
Rock blasting crew	0·287
Excavator greaser	0·026
After scalers	0·036
Truck drivers	0·165
Miscellaneous labour	0·111
Carpenter	0·009
Grinders of drill steel	0·020
Rock drill repairmen and compressor operator	0·026
Shift repairman	0·009
Shift electricians	0·026
Mine-car tippers	0·028
Excavator repairmen	0·009
Workshop workers	0·017
Tractor drivers	0·026
Total time	0·795

Equipment Used for Top Heading Operations

Excavators. Standard Marion 93-M machine, provided with 2½ cu. yard shovel and Ward-Leonard electrical equipment, Standard machine, but with the jib shortened by 75 cm. The capacity is a little more than 125 cu. m. of rock per hour with good loading. The average capacity for a full round is about 80 cu. m. per hour.

Trucks. For mucking out the broken rock, 14-ton Euclid trucks are used, most of them being equipped with a quarry body, i.e., a platform body with sloping sides. Loading is quicker than with the narrower standard platform body with vertical sides. The tyres of the truck are protected from stone spillage. The trucks can take heavier loads (15 to 16 tons) without strain, if required. Most of these platform bodies were manu-

HARRSELE HYDRO-ELECTRIC POWER PROJECT

DISCHARGE TUNNEL

GROUP OF HOLES	NUMBER OF HOLES	DRILLED METRES
1	26	208
2	24	192
3	48	362
4	52	389
NUMBER	150	1151

ADVANCE PER ROUND 7,8 m
ROCK EXCAVATED 1000 m³
NUMBER OF HOLES DRILLED 150
TOTAL DRILLED METRES
CUT 528 } 1151 m
STOPE 623 }
DRILLED METRES/m³ 1,15
CONSUMPTION OF EXPLOSIVES 0,84 KG/m³

*①U = SHORT DELAY BLASTING

DETONATOR No.	TIME OF DETONAT	NUMBER PER ROUND
0	0	3
①U	0,03	3
②	0,06	6
④	0,12	6
⑥	0,18	6
⑧	0,24	6
⑩	0,30	10
2	1,0	6
3	1,5	6
4	2,0	6
5	2,5	6
6	3,0	5
7	3,5	14
8	4,0	17
9	4,5	33
10	5,0	17
	NUMBER	150

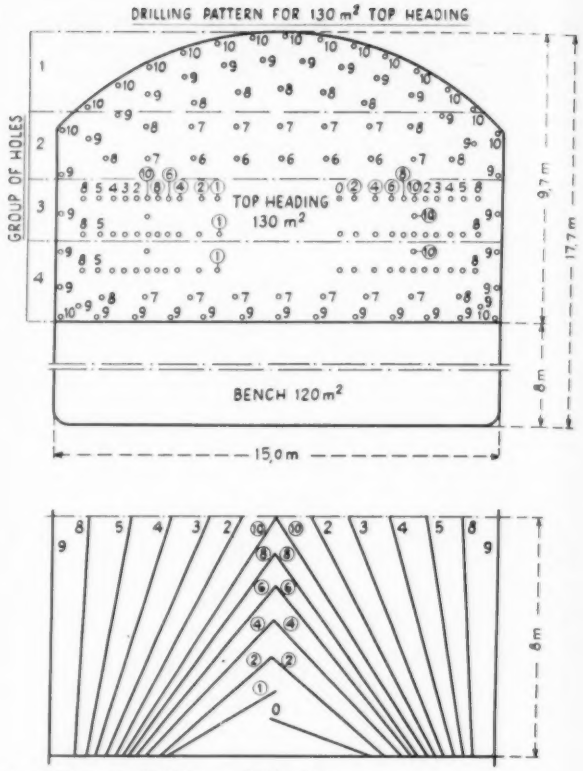

Fig. 4. Tables and diagrams relating to drilling and blasting

factured in Sweden by Jerfelds Mekaniska Verkstad, Örnsköldsvik.

Caterpillar. The scraping together of the broken rock before and during hauling is done by D8 Caterpillar fitted with a rope-operated shield. In the beginning a D6 was used, but was found to be insufficiently powerful. It is very important that the round should be well heaped before haulage begins, so that the loader can operate at full capacity immediately afterwards. The time spent on mucking a round has been reduced by about 1 hour with the introduction of this tractor. In view of the very large rounds, this is an important factor.

Fig. 5. Although the rock is usually sound there are weak patches which are reinforced by roof bolts

Floor surface. A lot of attention is paid to the floor surface of the tunnel. In this matter good work is being performed by a road scraper Caterpillar No. 12. As it is important to feed the trucks to the loaders continuously it is very desirable to have an even floor surface.

Jumbo. Jumbos are of the Swedish Power Board type, i.e., light tubular structures, each covering half the tunnel face. The jumbo units are transported on Euclid trucks.

Compressor. Compressed air is delivered by Atlas Copco AR4-E compressors. Both the compressors and aftercoolers are mounted on skidframes.

Rock Drills for Top Heading. For drilling, BBD 41WKC machines are used, having pneumatic pushers They have replaced the old well-known RH-67 machines. The cost of spare parts for the rock drill alone, excluding working costs, remained at 12 öre per drilled metre from the beginning of 1955. Twenty rock drills are used per drill crew. The machines can achieve 9·6 m. drill holes without difficulty.

Lift Truck. A Hyster 150 lift truck in combination with a platform erected on the fork has proved its excellence for the scaling of the ceiling and walls of the tunnel, as well as for other duties. The method

was introduced in the Laisvall mine, where the lift truck is also used as a jumbo. A certain amount of scaling, etc., is also carried out from a platform placed on the top of the excavator's jib. For this work the Atlas BBD 11 LTS trimming machine was used. The Hyster lift truck was also used for mounting iron girders of Dip 20, which serve, partly, as temporary supports and, partly, as a supporting construction when moulding the permanent concrete supporting girders. Used in conjunction with the lift truck is a Hyster Karry Krane, having a 4 ton capacity.

Moulding of support girders. The moulding of the girder supports is done by means of a concrete pump of the Blaw Knox type, which has proved very satisfactory. The concrete is transported from the concrete station to the moulding unit in the tunnel by means of lorries on which are fitted 2·5 cu. m. hydraulically operated tipping containers of the Svema B1B1 type.

As mentioned, the even rhythm of the blasting operations was interrupted in the beginning of September 1955, when poor rock was struck at the upstream end of the top heading. A little earlier kaolin-filled fissures in the rock had been discovered and the rock itself was "kaolinised" to a certain extent, its texture getting worse and worse. From time to time these fissures had a thickness of many centimetres. As kaolin readily disintegrates when exposed to moisture there was a great risk of falls in those areas where leakages occurred or could be expected to happen.

The blasting operations at the upstream end of the top heading could, however, be continued, although at a considerably reduced speed. As soon as a dangerous spot was encountered operations had to be interrupted to allow for supporting girders of reinforced concrete to be moulded. The blasting operations at the downstream end of the top heading were also interrupted to some extent by kaolin-affected rock. The occurrence of kaolin in the rock was an unpleasant surprise—not only to us but also to the geological experts—as it was not discovered in the drill cores when samples were obtained from the strata. This is a matter of considerable interest from a geological point of view.

Fig. 7. One-man rock drills are the accepted tools for Swedish tunnelling practice; this particular machine is equipped with an adaptor for roof-bolting operations

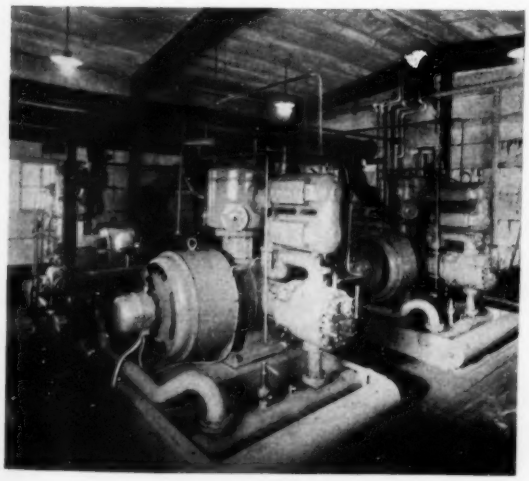

Fig. 6. Four skid-mounted compressor units which have the merit of not needing foundations. The housing consists of a welded steel framework with light-weight concrete wall and roof units

After a break for Christmas and New Year 1955, preparations were put in hand for benching operations at the downstream end of the tunnel. In the first place it was a question of blasting from the bottom of the top heading down to the bottom of the actual tunnel. It was decided to increase the cross section of the tunnel from 250 to 260 sq. m., which entailed raising the height of the bench from 8 to 8·7 m.

At the same time reinforcement was being needed at an accelerated tempo in the kaolin-affected area of the tunnel at the upstream end. It was found necessary to have about 350 m. of the tunnel completely lined with reinforced concrete and, in addition to the concrete girders, already in position, to arrange for more girders to be moulded. Extensive scaling of the roof and walls, accompanied by roof bolting, had to be carried out. The concrete lining had to be continued down to the bottom of the tunnel and this has meant that comprehensive reinforcing has had to be carried out in conjunction with the benching operations.

The drilling operations for benching are carried out from a jumbo which covers the whole width of the tunnel (15 m.). Ten Atlas Copco chain-fed rock drills (BBC42 RBL), having a feed length of 4·8 m., are mounted on the jumbo, each drill weighing 47 kg. Air consumption per machine is 6·8 cu. m. per min. at a pressure of 6 kg. per cu. cm. Sandvik $1\frac{1}{4}$ in. extension drill steels are used with 12 mm. water-flushing holes, Leyner shank, and 48 mm. Coromant tungsten-carbide 4-cross bits. Charging is done with pneumatic loading

apparatus and 25 mm. dynamite cartridges. Firing is with electric short-delay detonators.

Review of Earlier Tunnel-blasting Operations

It is now almost 20 years since the first tunnel-blasting operations based on the present method (full-face blasting with drilling from a movable jumbo) were carried out in Sweden. Considerable developments, of course, have taken place since then. The most important steps in progress were no doubt the change over from drifters mounted on columns to light rock drills having pneumatic pushers, and the introduction of Coromant tungsten-carbide-tipped drill steels. Since these radical changes were carried out the rock drills themselves and, more especially, the drill steels, have been considerably improved.

An impression of what has been achieved is obtained by studying Table III which gives the working time per cu. m. of the sectional rock removed at some of the well-known tunnelling projects for the rock blasting crew and for the full labour force.

TABLE III—WORKING TIMES FOR VARIOUS TUNNELS

Tunnel	Area	Length	Working time (years)	Time of rock blasting crew	Total time[3]
	sq. m.	m.		(hours per cu. m.)	(hours per cu. m.)
Harrmarby ...	33·5	800	1937-39	1·24	2·37
Järpen	105	4,500	1940-44	0·67	2·20
Hjälta	135	6,130	1944-49	0·425	1·85[4]
Dönje[1]	125	4,700	1948-52	0·343	1·01
Harrsele[2] ...	130	3,400	1954-55	0·287	0·80

(1) Data obtained from Mr. Bo Brom's report on the Dönje tunnel (Power Association's publication No. 4/1953). (2) Refers to the top heading of the Harrsele tunnel. (3) Excluding reinforcements. (4) Mucking in the Hjälta tunnel was done by means of diesel engine, normal-gauge railway trucks, and mine hoist. Various difficulties with the mechanical equipment during the postwar period contributed to the high operation and maintenance costs.

The blasting of the Hammarby track tunnel was carried out with the aid of drifters on columns and alloyed drill steel. Atlas RH-67 rock drills with pneumatic pushers were introduced in the Järpen tunnelling project and when work on the Hjälta tunnel began tungsten-carbide tipped drill steels had been introduced.

Latest Results

The first charge in connection with the bench blasting at the downstream end of the tunnel was fired on February 1 and at the upstream end of the tunnel on May 14. Up to and including the month of August the results given in IV had been achieved in blasting the 130m² bench:

1956	Downstream end of the tunnel	Upstream end of the tunnel	Total
	m.	m.	m.
February ...	80	—	80
March ...	111	—	111
April	85	—	85
May	160	77[1]	237
June	192[2]	148	340
July	46[2]	87[2]	133
August ...	166	233	399
	840	545	1,385

[1] May 14-31; [2] holiday month.

At the end of August there remains, practically speaking, 2,000 m. It is estimated that the blasting operations should be completed in February 1957. The rock in the downstream end of the tunnel is to a large extent poor and difficult to blast, which obviously has had an effect on the advance.

After working for a short time it was found that the drilling could be carried out with nine rock drills mounted on the drilling jumbo and evenly divided across the width (15 m.) of the tunnel. Furthermore, at each working place a wagon drill is used for the extra drilling which is sometimes required in addition to the drilling from the jumbo. The interval between the run of holes is 2·2 m.

At each end of the tunnel the piece-work crew consists of 11 men, divided as follows:

3 men to operate the nine rock drills on the drilling jumbo.
5 men to look after the charging, extra drilling with the wagon drill and firing.
3 men (1 per shift) to operate the excavator.

In addition, some purely manual operations are carried out on a small scale. Special workers scale the walls and muck out the excavated rock by means of 14-ton Euclid trucks, etc.

Drilling, charging, and firing are carried out during the day shift and mucking during three shifts. The excavators are at work during 14 of the week's 18 shifts on three-shift operation. Two "idle" shifts are caused by the current regulations regarding three-shift subterranean operations and the other two vacant shifts are accounted for by a desire not to overburden the excavators, and to allow time for their maintenance.

Rock Drills for Kariba

Orders for British drilling equipment have now been placed by Impressit South Africa (Pty.) Ltd., the Italian group of contractors responsible for major sections of the Kariba Gorge hydro-electric scheme in Rhodesia. These drills, made by Holman Bros. Ltd., of Camborne, will be supplied from the firm's South African factory at Johannesburg, which already supplies more than half the rock drills in use in the Rhodesias. Similar machines are already employed at the site as they are being used by The Cementation Co. Ltd., contractors for the diversion tunnel.

Ferranti Transformers for TVA

A contract for four 26,667 kVA single-phase forced-air-cooled outdoor-type transformers has been awarded to Ferranti Ltd. by the Tennessee Valley Authority, U.S.A. These transformers will form one 80,000 kVA 154/69/13·2 kV three-phase bank of transformers, the fourth transformer being a spare unit, and will be installed in the Pigeon Forge Substation, Knoxville, Tennessee. This is the sixth order awarded to Ferranti Ltd. by the U.S.A. in recent years and brings the total number of transformers supplied, or under construction, to 45 units of a total capacity of over two million kVA.

Axial Thrust in Double-discharge Turbines

Professor Dipl.-Ing. L. A. Haimerl, Munich-Pasing, shows that in the case of double-discharge Francis turbines operating at low specific speeds slight differences in the cross-sections of the runner clearances are enough to bring about substantial unilateral axial thrusts, and thus justify thrust bearings of appropriately ample dimensions

IN horizontal double-discharge turbines (Figs. 1 and 2) though perfectly symmetrical in construction, it would appear at first sight there is no resultant axial thrust, although, of course, internal axial forces occur, these being balanced because they are symmetrical. It would seem, therefore, that double-discharge turbines would require no special axial thrust bearing, but this is not the case, as everyone knows who has made a closer study of this type of turbine. Symmetrical double-discharge turbines fitted with very large thrust bearings are by no means uncommon, and this compels us to enquire how far such a precaution is justified and what kind of explanation is involved. Let us consider Fig. 3, which shows a slow-running double-discharge turbine of the Francis type with an external clearance S_1, and, at the mouth of the draft tube, clearance S_3. These clearances must be determined in such a way as to impede as much as possible the non-permissible travel of the water from the guide vanes to the draft tube around the outer surface of the runner, while leaving enough play between the runner and the fixed parts of the casing to prevent any contact between them. As shown in the diagram, we merely provide a simple annular clearance with radial play s_1 and s_3, and effective lengths L_1 and L_3, respectively. In the case of such clearances, K. Just* calculates the flow passing the turbine as follows:

$$\mu = \frac{1}{\sqrt{\frac{L}{25s} + 1{\cdot}5}} \qquad \ldots(1)$$

* K. Just: "Ueber Labyrinthspalte" (On labyrinth clearances). Dingler's Polytechnisches Journal, Vol. 326, 1911.

In practice we assess the width of the clearance at

$$s = \frac{D_1}{2500} + 0{\cdot}4 \text{ mm.} \qquad \ldots(2)$$

s and runner diameter D_1 being expressed in millimetres.

The quantity of water which forces its way through clearances S_1 and S_3 around the rim of the runner also fills the space between runner and turbine casing. It may be assumed that this enclosed water annular revolves with half the angular velocity of the runner, and according to the law of rotating fluids causes a parabolic distribution of pressure. We obtain therefore the angular velocity of the water annular between runner and casing from: $\omega_1 = \frac{\omega}{2}$ ...(3)

Due to the rotary motion of water in the annular space extending between clearances S_1 and S_3 and, consequently, between radii r_1 and r_3, there results a difference in pressure head of

$$h_{pb} = \frac{\omega_1^2}{2g}(r_1^2 - r_3^2) = \frac{\omega^2}{8g}(r_1^2 - r_3^2) \qquad \ldots(4)$$

in which h_{pb} represents in the pressure-head graph (Fig. 3) the height of the paraboloid section lying between r_1 and r_3. In front of the clearance S_1, the pressure head, according to the Bernouilli equation, is

$$h_1^{abs} = H_D + h_{atm} - \frac{c_1^2}{2g} - h_{vl.t} \qquad \ldots(5)$$

At the outlet cross-section "3" (cross section of draft-tube mouth) the effective pressure head is given by the expression

$$h_3^{abs} = h_{atm} - H_S - vH \qquad \ldots(6)$$

in which H_D = pressure head of turbine,

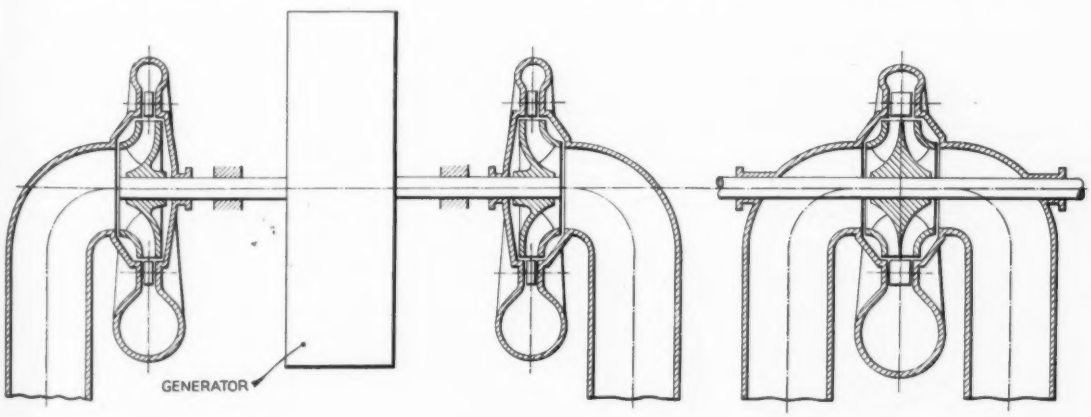

Fig. 1

Fig. 2

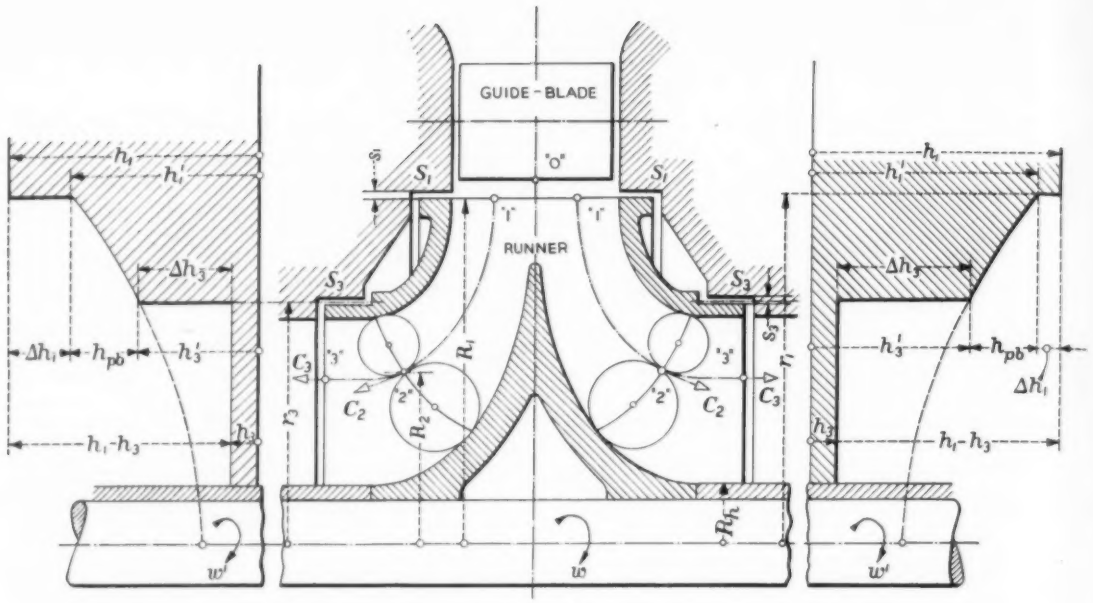

Fig. 3

H_s = suction head of turbine.
$H = H_D + H_s$ = net head of turbine,
h_{atm} = atmospheric head,
c_1 = absolute admission velocity into the runner blades,
c_2 = absolute exit velocity from the runner blades,
c_3 = absolute exit velocity at the suction mouth of the runner,
vH = energy recovered in draft tube,
h_{vLt} = pressure-head loss in guide vanes, spiral casing included.

If we assume that approximately $c_2 = c_3$, we then have $h_2^{abs} = h_3^{abs}$.

In turbines with a small or medium specific speed, to which these considerations more particularly apply, the amount of energy recovered in the draft tube is of no great significance and we may simply neglect it. It then follows that the pressure-head difference between "1" and "3" is

$$h_1 - h_3 = H - h_{vLt} - \frac{c_1^2}{2g} \qquad ...(7)$$

We now arrive at the pressure-head differences at clearances S_1 and S_3. The amount of clearance water in one half of the double runner (Figs. 1 or 3) or in a single runner without compensation holes (Fig. 2) is expressed by means of the Torricelli formula:

$$Q_{sp} = a_1\mu_1\sqrt{2g\Delta h_1} = a_3\mu_3\sqrt{2g\Delta h_3} \qquad ...(8)$$

in which a_1 and a_3 = developed cross section of clearance, and $a_1\mu_1$ and $a_3\mu_3$ = effective developed cross section of clearance.

$$a_1 = 2r_1\pi s_1 \qquad a_3 = 2r_3\pi s_3 \qquad ...(9)$$

We can now first obtain from (8) the ratio of the pressure-head differences

$$\frac{\Delta h_1}{\Delta h_3} = \left(\frac{a_3\mu_3}{a_1\mu_1}\right)^2 \qquad ...(10)$$

and then, from the graphs in Fig. 3:

$$h_1 - h_3 = \Delta h_1 + \Delta h_3 + h_{pb} \qquad ...(11)$$

By combining with (10) we can solve the equation for Δh_1 or Δh_3:

$$h_1 - h_3 = \Delta h_1 + \Delta h_1\left(\frac{a_1\mu_1}{a_3\mu_3}\right)^2 + h_{pb}$$

$$\Delta h_1 = \frac{h_1 - h_3 - h_{pb}}{1 + \left(\frac{a_1\mu_1}{a_3\mu_3}\right)^2} \qquad ...(12)$$

Together with (11) we obtain:

$$\Delta h_3 = \frac{h_1 - h_3 - h_{pb}}{1 + \left(\frac{a_3\mu_3}{a_1\mu_1}^2\right)} \qquad ...(13)$$

If we now insert Δh_1 or Δh_3 into the Torricelli formula (8) we have then the possibility of calculating the amount of clearance water. Applied to the whole turbine, the result is to be multiplied by 2, provided we have to deal with perfectly symmetrical conditions.

Following these general preliminary considerations, let us now tackle the axial-thrust problem itself. Assuming that the hatched surfaces of the graphs in Fig. 3 revolve around the turbine axis, the resulting solids of revolution represent the axial thrusts on both sides. For clarity these surfaces are shown differently in Fig. 4. Δh_1 on the left side is assumed to be considerably greater than Δh_1 on the right side, these conditions being reversed for Δh_3. Such differences can occur in the actual turbine, and this brings us face to face with the very essence of our problem. Let us suppose equal pressure heads h_3 for both runner halves, as well as equally high segments h_{pb} of the paraboloids of revolution, then differences in the graph areas can only be brought about by different throttling in the clearances. This would result in a residual axial thrust of:

$$\Delta F = F_l - F_r \qquad ...(14)$$

in which it is assumed that $F_l > F_r$,

F_l = axial thrust of the left runner half, directed to the right as shown in Fig. 4.

$$F_l = \pi(r_1^2 - R_h^2)h_3\gamma + \pi(r_1^2 - r_3^2)\Delta h_3\gamma + \\ + \pi(r_1^2 - r_3^2)\frac{h_{pb}}{2}\gamma;$$

F_r = axial thrust of the right runner half, directed to the left:

$$F_r = \pi(r_1^2 - R_h^2)h_3\gamma + \pi(r_1^2 - r_3^2)\Delta h_{3r}\gamma + \pi(r_1^2 - r_3^2)\frac{h_{pb}}{2}\gamma$$

Substituting these two expressions in (14), we have: $\Delta F = \pi(r_1^2 - r_3^2)(\Delta h_{3l} - \Delta h_{3r})\gamma$ or

$$\Delta F = \pi r_1^2 \left[1 - \left(\frac{r_3}{r_1}\right)^2\right](\Delta h_{3l} - \Delta h_{3r})\gamma \qquad ...(15)$$

and taking Δh_3 from (13) we obtain:

$$\Delta F = \pi r_1^2 \left[1 - \left(\frac{r_3}{r_1}\right)^2\right]\left\{\frac{h_1 - h_3 - h_{pb}}{1 + \left(\frac{a_3\mu_3}{a_1\mu_1}\right)_l^2} - \frac{h_1 - h_3 - h_{pb}}{1 + \left(\frac{a_3\mu_3}{a_1\mu_1}\right)_r^2}\right\}\gamma$$

or

$$\Delta F = \pi r_1^2 \left[1 - \left(\frac{r_3}{r_1}\right)^2\right](h_1 - h_3 - h_{pb})$$

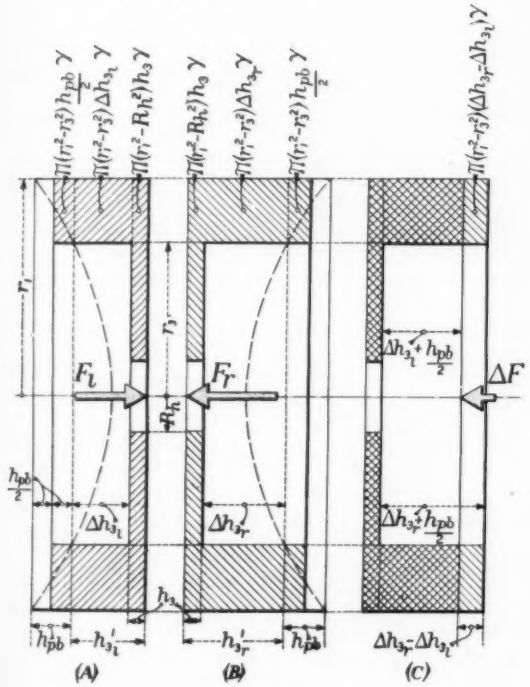

Fig. 4

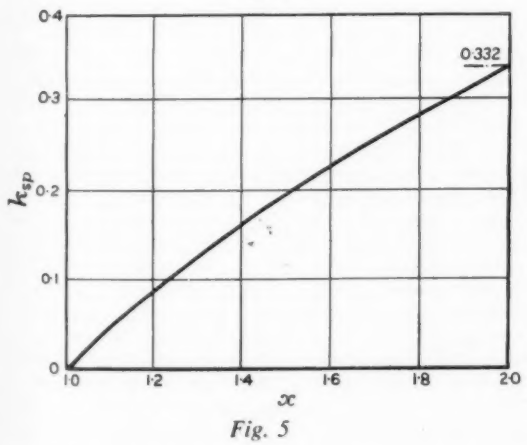

Fig. 5

$$\left\{\frac{1}{1 + \left(\frac{a_3\mu_3}{a_1\mu_1}\right)_l^2} - \frac{1}{1 + \left(\frac{a_3\mu_3}{a_1\mu_1}\right)_r^2}\right\}\gamma \qquad ...(16)$$

This formula represents the final result of our considerations, and we shall now deal with a few special instances. We already realise that the ratio r_3/r_1, which is about equal to the runner ratio R_3/R_1 has a considerable influence on ΔF. The smaller r_3/r_1 or R_3/R_1, the greater residual thrust ΔF, provided the expression in braces does not happen to shrink to zero. This latter braced expression is dimensionless and gives us an idea of the influence of the clearance on residual thrust ΔF. This may be termed the coefficient of clearance influence, so that

$$k_{sp} = \frac{1}{1 + \left(\frac{a_3\mu_3}{a_1\mu_1}\right)_l^2} - \frac{1}{1 + \left(\frac{a_3\mu_3}{a_1\mu_1}\right)_r^2} \qquad ...(17)$$

The expressions standing in (16) in front of the braces are dependent on the design and on the specific speed n_s of the turbine respectively. The smaller r_3/r_1 or R_3/R_1, the smaller also is the specific speed of the machine, as is generally known from the usual drawings of runners. As however r_3/r_1 decreases, the residual thrust, according to (16) increases in the case of our inserting for k_{sp} a determined value differing from zero. When dealing therefore with our special problem of axial thrust, more attention must be devoted to the double-discharge slow runner than perhaps to a turbine running at a higher specific speed.

Let us, for instance, consider a Francis turbine with *single discharge*. The empirical values applying to this particular instance, smooth running, and absence of swirl at the outlet being assumed, $\frac{r_3}{r_1} = \frac{2}{3}$ angular velocity $\omega = \frac{u_1}{R_1} = u_1 \frac{\sqrt{H}}{R_1}$ in which u_1 is the peripheral speed at the inlet at $H = 1$ m.; $u_1 = 2{\cdot}93$ m. per sec.; $\omega = \frac{2{\cdot}93}{R_1}\sqrt{H}$

According to (7) we had: $h_1 - h_3 = H - h_{vLt} - \frac{c_1^2}{2g}$

Estimated losses in the guide vanes $h_{vLt} = 0{\cdot}05H$ at $D = 1$ m. diameter; absolute speed of admission to the runner $c_1 = 3{\cdot}05$ m. per sec. at $H = 1$ m. head and at the above-mentioned specific speed; and $g = 9{\cdot}81$ m./sec.^{2} for earth acceleration. Thus:

$$h_1 - h_3 = H - 0{\cdot}05H - \frac{(3{\cdot}05\sqrt{H})^2}{2 \times 9{\cdot}81} = 0{\cdot}476H$$

According to (4): $h_{pb} = \frac{\omega^2}{8g} r_1^2 \left[1 - \left(\frac{r_3}{r_1}\right)^2\right] - \frac{(2{\cdot}93\sqrt{H})^2}{8 \times 9{\cdot}81 R_1^2} r_1^2 \left[1 - \left(\frac{2}{3}\right)^2\right]$

whence, with $r_1 \approx R_1$: $h_{pb} = 0{\cdot}061 \times H$;

with n_s = about 100, $\pi r_1^2 \approx \frac{\pi}{4} D_1^2$ and $\gamma = 1{,}000$ kg./cu. m. equation (16) is reduced to

$$\Delta F = \frac{\pi}{4} D_1^2 . 1000 \left[1 - \left(\frac{2}{3}\right)^2\right](0{\cdot}476H - 0{\cdot}061H)k_{sp}$$

$$\therefore \Delta F = 181 D_1^2 H k_{sp} \text{ (for } n_s \approx 100) \qquad ...(18)$$

At the high speed instanced, the coefficient of clearance influence k_{sp} (17) is the only value which remains

variable. In the case of a turbine in normal condition

$$\left(\frac{a_3\mu_3}{a_1\mu_1}\right)_t = \left(\frac{a_3\mu_3}{a_1\mu_1}\right)_r$$

and thus $k_{sp} = 0$. The unilateral axial thrust disappears, which, in fact, corresponds to the ideal case. An extreme case for ΔF could now be derived purely mathematically by simply assuming

$$\left(\frac{a_3\mu_3}{a_1\mu_1}\right)_t = 0 \text{ and } \left(\frac{a_3\mu_3}{a_1\mu_1}\right)_r = \infty$$

Then, the coefficient of clearance influence reaches the maximum value $k_{sp} = 1$. This would mean that, at $\frac{a_3\mu_3}{a_1\mu_1} = 0$, the clearance at the draft-tube mouth S_3 must cause full throttling of the clearance water. On the other hand, at $\frac{a_3\mu_3}{a_1\mu_1} = \infty$, the outer clearance S_1 would block any flow of water. However, assumptions of this kind would lead us too far away from reality, and we shall not proceed with the investigation of this extreme case. It remains however worth knowing that, according to the ratios of the effective clearance cross sections, a margin of 0 to 1 for k_{sp} is theoretically possible. To move closer into range of actual practice, we shall assume that only one of the four clearances of the turbine is somewhat worn, the remaining three clearances retaining their normal dimensions, and we shall further suppose that the worn clearance is either an outer clearance S_1, or a clearance S_3 of the draft-tube mouth. A comparative calculation, which we shall not further pursue in this article, shows us however that the most unfavourable conditions arise when one of the two clearances of the draft-tube mouth is assumed to be worn. We shall then simply suppose that the initial effective cross section of the clearance ($a_3\mu_3$) has increased x times. For the normal case, we shall assume for our turbine moving at $n_s = 100$, that $\frac{a_3\mu_3}{a_1\mu_1} = \frac{2}{3}$. It then follows, in the instance of an alteration in the effective cross section of the right clearance, that

$$k_{sp} = \frac{1}{1+\left(\frac{2}{3}\right)^2} - \frac{1}{1+\left(x\,.\,\frac{2}{3}\right)^2} = \frac{9}{13} - \frac{1}{1+\left(x\,.\,\frac{2}{3}\right)^2}$$

Accordingly, the curve shown in Fig. 5 can be plotted as a dependent variable of wear x. In the case of the right clearance of the draft tube being worn to double its initial effective cross section, there occurs a residual thrust of

$$\Delta F = 181\,D_1^2 H 0{\cdot}332 = 60\,D_1^2 H.$$

The plotting shows, therefore, that in spite of the neat symmetrical construction, there is a possibility of fairly substantial residual thrusts in double-discharge turbines. Any unequal wear of the clearance produces a lesser or greater amount of axial thrust which can be absorbed without impairing operating reliability only by appropriately designed bearings.

We should like to make a further comparison with a rule-of-thumb formula which is often used for the calculation of axial thrust in single-discharge turbines of the Francis type:

$$F_{sd} = n_s D_1^2 H \qquad \ldots(19)$$

in which F is expressed in kg., D_1 and H in metres, n_s being the specific speed (metric). If this formula is now to be applied to a double-discharge turbine, the following equation is sometimes advocated:

$$\Delta F = \frac{F_{sd}}{2} \qquad \ldots(20)$$

It is therefore stated that, in the instance of an unfavourable wear of the clearance, the residual thrust of a double-discharge turbine is half the axial thrust of a single-discharge single wheel. This rule-of-thumb formula coincides fairly well with the above theoretical explanations in the case of turbines with a low specific speed but, when applied to machines in higher speed ranges, leads to thrust-bearings of enormous dimensions.

Aluminium Transmission Lines

At the present time, in spite of the enormous amount of overhead electrical transmission and distribution work that is going on throughout the world, there is a surprising dearth of published literature which serves to give engineers a reasonably complete introduction to the problems associated with overhead transmission conductors.

In an effort to fill this gap Aluminium Union Limited, Canada, have produced an important new handbook entitled "Aluminium Transmission Lines" which we believe will have a very definite value both to students and to engineers actually engaged in this branch of electrical technology. This publication is excellently produced and illustrated and gives adequate information on methods of calculation, together with easy reference tables and charts to enable engineers to carry out any normal, straightforward line design problem without the need of further references.

The publication is intended for distribution throughout the world, and in addition, a domestic version is available for readers in the United Kingdom, this being issued by the Northern Aluminium Co. Ltd., an associate of Aluminium Union Limited.

Mannesmann Tower at Vienna

The most conspicuous feature of the 64th Vienna Fair, almost 500 ft. high and visible miles around, is the tower erected by the Mannesmann Works, the pioneers of the seamless steel tube, in the centre of the Rotunda Fair Grounds. Similar tubular structures had already been displayed elsewhere, at Düsseldorf, Hannover and Sao Paulo, to mention three places only, but none had ever approached the height which now makes the Vienna tower the highest building in Austria. Compared to the traditional type of sectional-steel tower, such as the 985 ft. Eiffel Tower or that at Blackpool, 520 ft., the reduction in weight achieved by the use of seamless steel tubes is striking. For instance, if the Eiffel Tower had been made of Mannesmann tube sections, its weight would have been no more than 200 tons instead of 7,000. This means a saving in steel of no less than 97·15%, not to mention the fact that the tubular towers, being much less subjected to corrosion, require considerably less maintenance work. A further advantage of the tubular member over the traditional steel section is that, weight being equal, resistance to buckling is much stronger, and the structure stands up better to wind pressure. All the components of the Vienna tower were manufactured in Düsseldorf and dispatched to Vienna ready for assembly on site.

Fig. 1. Closing the Gunhães dam. The intake to the Gunhães-surge tank is in the background

Salto Grande, Brazil

This description of a 100 MW development on the Santo Antonio River in the State of Minas Gerais has been specially written for this journal by the technical staff of Centrais Eletricas de Minas Gerais. The remoteness and inaccessibility of the site imposed special problems in construction and exercised a determining influence on design

PART ONE

THE Salto Grande development is the most important project at present under construction by Centrais Elétricas de Minas Gerais S.A. (CEMIG) as part of a State-wide electrification programme established by Dr. Juscelino Kubitschek, Governor of the State of Minas Gerais, and carried out during his five-year period in office. The State is one of the most important in Brazil, with a population around 8½ million inhabitants and an area of 590,000 sq. km., comparable to that of France. The State programme, necessary because a general power shortage in the area had for many years seriously crippled industrial progress, included initially the construction of five hydro-electric stations with a total generating capacity of 200 MW, 510 miles of 161, 138 and 69 kV transmission lines and several step-down substations (Fig. 2). The plan was conceived primarily to supply large new industries, especially those taking advantage of the natural resources of the region: iron, manganese, bauxite, limestone, etc.

CEMIG is a State-owned organisation founded for the planning and carrying out of this electrification programme. This article presents the points of major interest in regard only to the Salto Grande power station, in view of the particular problems involved due to the size of the undertaking as compared with the available facilities for work of this nature in Brazil in localities remote from the main populated centres. The load centre of the area covered by CEMIG activities is the region extending approximately 120 miles around the State Capital—Belo Horizonte. In this area, due to lack of available fuel and transportation facili-

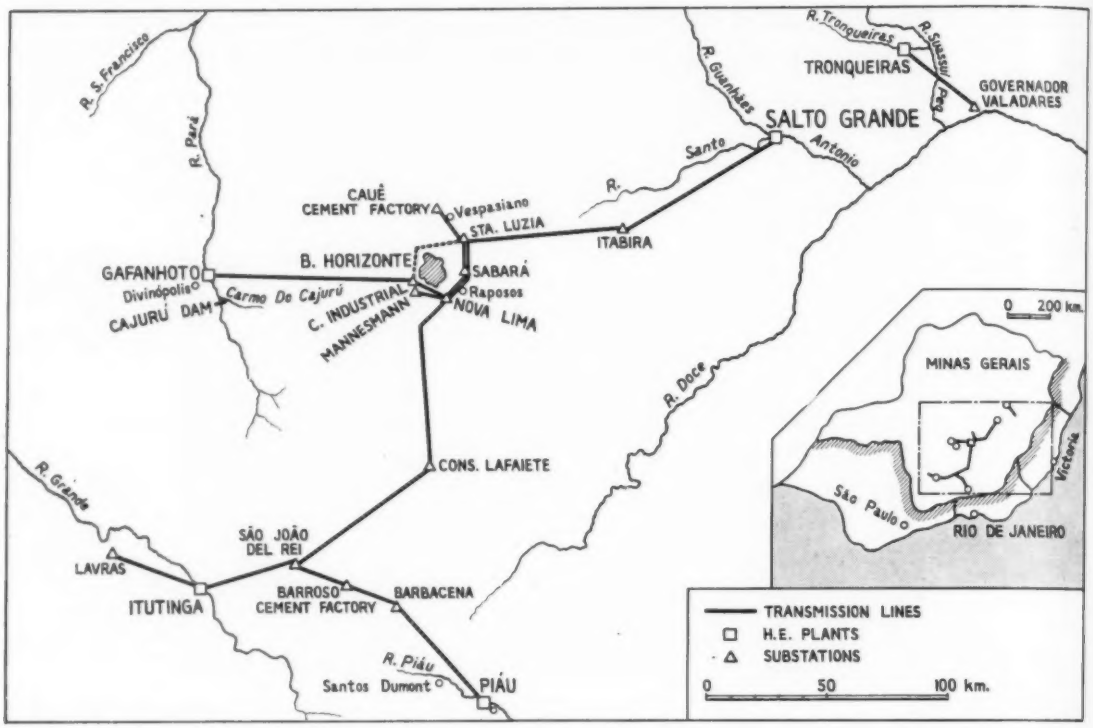

Fig. 2. Map of central Minas Gerais showing the CEMIG system

ties, large-scale coal and oil-burning power plants are economically out of the question. At the same time, due to the nature of the load, a generating load factor of approximately 60 to 70% is required during the dry season.

The Santo Antonio River Power Potential

At approximately 100 miles north-east of Belo Horizonte the Santo Antonio River, of the Rio Doce basin, presents several possibilities of hydro developments on a 20 mile stretch with a natural drop of 155 m. Large storage-reservoir sites for seasonal regulation of river flow are available on the Guanhães River, a tributary of the Santo Antonio River. The most important site is Salto Grande with a capacity of 100 MW, but there are many other sites that can be economically developed with a total capacity (including Salto Grande) of about 350 MW.

The principal disadvantage of these sites was their remote and inaccessible location in a very thinly populated region with no highways, roads or other means of transportation and only very small communities located between the small and steep hills that characterise the region.

Salto Grande

Construction of a hydro plant at Salto Grande had been under consideration since 1948 due to the relatively high head available (about 90 m.) and the possibilities of cheap land for a reservoir. The State Government, through one of its departments, had several studies made during the period 1949-1950 and established the main features of the project.

Hydraulic control equipment, turbines, generators, step-up substation and transmission equipment for one half of the final capacity were purchased, and construction began in 1950. Unfortunately, unforeseen difficulties arose due to the lack of sufficient preliminary investigation and the discovery of difficult geological foundation conditions. When the project was transferred to CEMIG, in 1951, construction at the site was practically at a standstill and less than 5% of the hydraulic works required had been completed. The main transmission line, however, was nearly complete and all the hydraulic and electrical equipment had been received.

On the basis of an extensive geological research programme, it was found advisable to revise the original layout completely, although it was necessary to maintain the main features to permit use of the purchased equipment as far as possible. Due attention was paid in the new design to facilitate construction and supplies to the site. It was found necessary to enlarge and reconstruct the existing access roads, and provision was made to permit use of unskilled labour to the greatest possible extent.

The station will have a final installed capacity of 100 MW and will produce approximately 285 million kWh per annum on initial operation and approximately 730 million kWh when completed. In order to regulate the expenditure in accordance with the expected load growth over a longer period, construction was divided in two stages, with initial operation at 36 MW capacity under reduced head.

Two supplementary storage reservoirs are planned upstream, and are now being designed. With these it will be possible to operate the plant 365 days a year at near 95% load factor even during exceptionally dry

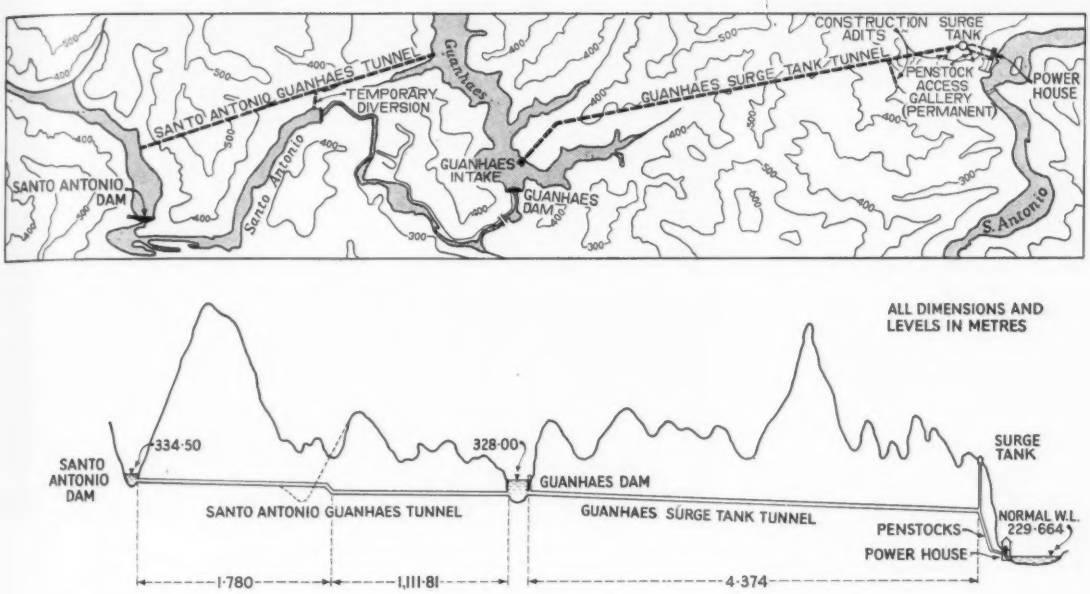

Fig. 3. Map and profile diagram of the Salto Grande development

years. This is of great value on an interconnected system supplied exclusively by hydro stations, and will permit economical construction of low-head plants close to the load centres, operable on lower load factors, such as Itititinga, for example*. Salto Grande will thus operate at the base of the load curve in the CEMIG system, taking the place reserved to the steam plants in countries where they can be economically used.

* See WATER POWER. January 1954, page 28.

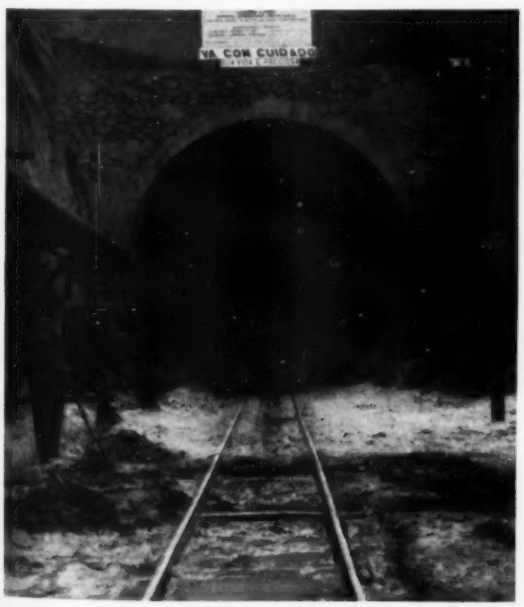

Fig. 4. Portal of Guanhães tunnel with a finished cross-section of 23·73 sq. in.

Hydraulics and Civil Works

The general layout of the Salto Grande development is shown in Fig. 3. The waters of the Santo Antonio River are diverted to its tributary, the Guanhães River, where a storage reservoir is established; from this reservoir water is taken through a long tunnel to the surge tank. There are two steel penstocks, each supplying a group of two turbines at the power house located on the Santo Antonio River, downstream from the confluence with the Guanhães River.

The Guanhães storage reservoir is unnecessary in the initial stage of the development, as the minimum dry-season river flow is approximately equal to the full gate discharge of two turbines.

Therefore in this stage the Guanhães dam is raised only up to the required level for the tunnel intake, and the Santo Antonio River is diverted by a temporary dam, with a short connecting gallery. The gross head will be approximately 80 m. and the useful head 76 m., with a discharge of about 54 cu. m. per sec. through the turbines.

When the installation is completed the Guanhães dam will be raised about 19 m. and a permanent diversion dam, with intake tunnel, will be built on the Santo Antonio River, upstream from the temporary first-stage installation. The gross head will be approximately 98 m. and the useful head 90 m., with a discharge of about 130 cu. m. per sec. through the four turbines. Available storage in the Guanhães reservoir will be 58 million cu. m.

The main features of the various structures are as follows:

First Stage

Santo Antonio Diversion—This is a small gravity diversion dam, about 9·5 m. in maximum height and 127 m. long, with 78 m. of spillway. A fixed-wheel gate, 4 × 6·5 m., is provided. The structure is built of mass concrete, with a total volume of approximately 4,300 cu. m.

The intake is a small concrete structure with one fixed-wheel gate, 4 × 6·5 m., and protective trash racks.

Santo Antonio-Guanhães Tunnel (Fig. 4)—This tunnel has a total length of 1,310 m. and a cross section of 23·73 sq. m. A concrete lining is used on a total length of about 750 m. The outlet to the Guanhães reservoir is provided with a special structure which permits installation of stoplogs and provides access when required to unwater the tunnel for inspection or maintenance.

Guanhães Dam (Fig. 1)—This is an overflow gravity concrete dam, designed for enlarging in the second stage. It is about 17·50 m. high and 110 m. long, with about 80 m. of spillway and a total volume of approximately 14,720 cu. m. of concrete. Two 1·80 m. diameter Howell-Bunger valves are installed, electrically operated, each for 56 cu. m. per sec. discharge at 33 m. head.

Guanhães Intake (Fig. 4)—This structure is the intake for the main tunnel and penstocks and is provided with two 4 × 6·5 m. fixed-wheel gates, with electrically operated hoists, trashracks and a mechanical trash rake.

Guanhães-Surge Tank Tunnel—This tunnel has a length of 4,374 m. and is at present the largest in Brazil. It is concrete lined, with a finished circular section 6·53 m. in diameter.

Surge Tank (Fig. 6)—The surge tank is of the restricted-orifice type, 61 m. high and 14·5 m. in diameter, concrete lined. It is provided with an expansion chamber close to the base and a steel-lined specially shaped water passage below the orifice to increase the velocity of flow at this point and thus improve the hydraulic stability of operation of the plant. Two caterpillar-type gates, electrically operated by hoists at the top of the surge tank, are provided for the penstock intakes. These gates measured 2·80 × 4·40 m. each and are designed for an operating pressure head of 65 m.

Fig. 5. A view of the surge shaft

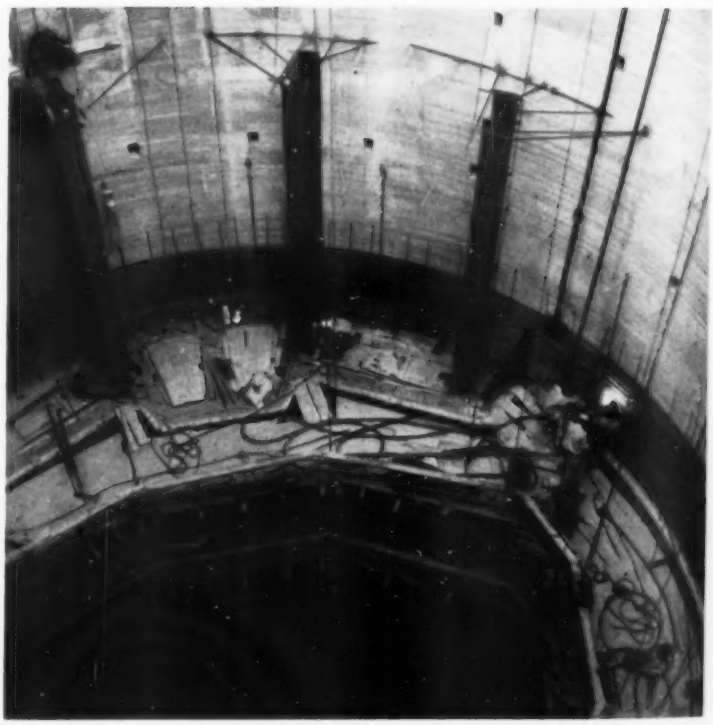

Fig. 6. Assembling the penstock gate guides inside the surge shaft

Penstocks—The steel penstocks, of welded construction, are carried down to the power house through tunnels driven in the rock. There is a section of single piping 176 m. long and 4 m. in diameter supported on concrete saddles within a horseshoe-section tunnel, 5·70 × 5·20 m. clear. At the end of this section there is a Y-piece, from which proceed two penstocks, 69 m. long, one for each turbine, with a diameter varying from 3·00 m. down to 2·743 m. One of these is set in concrete within a 3·55 m. diameter tunnel, the second being on saddles within a horseshoe-section tunnel, 4·70 × 4·40 m. clear, in order to permit access to the main penstock.

All water-control equipment for the first-stage construction was supplied by S. Morgan Smith Co., U.S.A., with the exception of the surge-tank penstock intake gates, which were supplied by Soc. Terni, Rome, Italy.

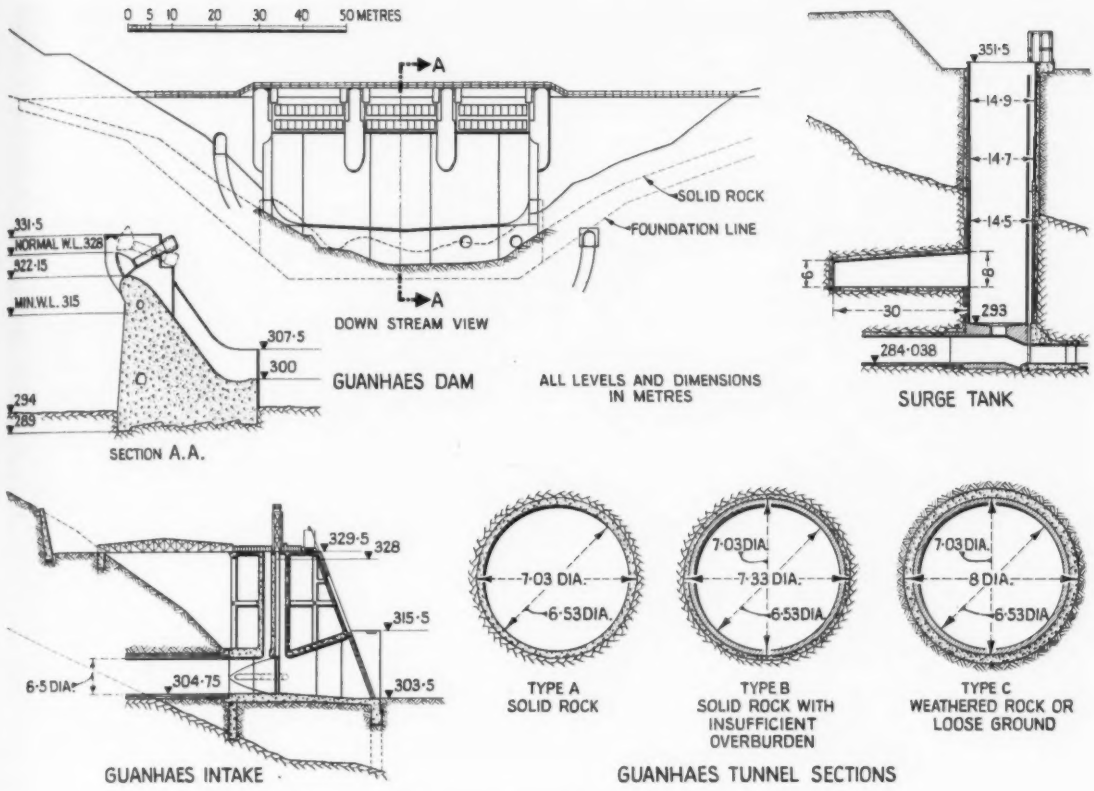

Fig. 7. Drawings of Guanhães dam, intake, tunnel and surge shaft

Second Stage

Santo Antonio Dam—This dam will be located approximately 4 km. upstream from the temporary first-stage structure. It will be 34·5 m. high and 322 m. long, a concrete gravity dam, with 10 taintor-type spillway gates, each 6 m. high and 10·5 m. wide, electrically operated.

Santo Antonio Intake—This structure will be about 700 m. upstream from the dam, with one fixed-wheel gate, 4 × 6·5 m., electrically operated, and protective trashracks.

Santo Antonio-Guanhães Tunnel—An additional length of 1,600 m. of tunnel will be driven to connect with the stretch completed during the first-stage construction. It will not be lined unless necessary due to unforeseen rock conditions during excavation, as it is at a higher level and will not normally operate under pressure. The cross-sectional area will also be 23·73 sq. m. The total length of tunnel will therefore be approximately 2,900 m.

Guanhães Dam—The completed dam will be 36 m. high and 248·8 m. long. Three taintor-type spillway gates will be provided, each 6 m. high and 16·5 m. wide, electrically operated.

The Guanhães intake, tunnel and surge tank were completed in the first stage.

Penstocks—A second system of penstocks similar to that of the first stage will be installed. As the two turbines will be slightly larger than those installed in the first stage, the main penstock, 176 m. long, will be 4·5 m. in diameter and the two branches, each 69 m. long, will be 3·10 m. in diameter. All these penstocks will be encased in concrete, the main section within a 5·70 m. diameter tunnel and the branches within 3·55 m. diameter tunnels.

Power Station—The power house is conventional in design, a reinforced-concrete structure founded on solid rock. The foundations for the main units, which are of the vertical Francis type, are entirely independent. The back of the power house, at the penstock entry, is protected by a massive concrete retaining wall.

Separate floors are provided for: (a) turbines, valves, shop area and assembly; (b) main generators, regulators, auxiliaries and service equipment, and (c) electrical control room, offices and annexe. The generator hall is equipped with a 170 ton travelling crane including an auxiliary hook for 30 ton service. Apertures are provided for handling of the main valve and turbine parts through the generator floor. The turbines discharge directly into the river under a bridge leading to the substation. A gallery is provided for access to the draft tube and a sump gallery is run at the lowest level for pump drainage.

Construction Problems

The major difficulties in construction of this project were due to lack of transportation facilities and equipment. The nearest railroad, of 1 m. gauge, at Ipatinga, a very small community, is 75 km. distant from the job site. The nearest road, that from Belo Horizonte to Guanhães, is 65 km. from Salto Grande at its closest

Fig. 8. General view of penstock welding yard

point. It was necessary to build these roads, in difficult terrain, to permit traffic in any weather, no easy matter taking into account the sharply defined rainy season, the hilly nature of the region and the special drainage and landslide difficulties. The great majority of labour for this work had to be brought into the area, lodging and supplies provided and all necessary communication established.

It was found necessary to provide storage facilities both at Ipatinga and at a point midway on the road from Belo Horizonte.

The greater part of imported materials and equipment were received at the port of Vitoria and brought by rail to Ipatinga. Materials and equipment of Brazilian origin were forwarded from Belo Horizonte.

To expedite administration from the head offices in Belo Horizonte, an air strip was built relatively close to the plant, of a size sufficient to accommodate four-passenger planes, and permanent radio communication established at all key points.

Camp

As there was no community within a reasonable distance from the job that could be used as a base for operations, it was necessary to build a complete small town to house the construction personnel and to provide all the required facilities at the site. The total number of employees reached a figure of 2,700 men, and the population of the construction town approximately 8,000. Due to the topography of the region and the distance between the various structures it was necessary to spread the housing and facilities over a large area.

Facilities provided included schools, a hospital, pharmacy, police, cinema, stores, butchers, water supply, lighting, drainage and sewers and sports fields. The cost of the housing and facilities reached a figure of about Cr$70,000,000·00 (US$1,400,000*) and the administration of the town was one of the major problems of the job.

Power for operation of the construction equipment, a great part of which was electrically operated, was obtained initially from two small hydro-electric units, with a combined capacity of 900 kW installed on an affluent of the Guanhães River and later reinforced with the supply from the Itabira transmission system, through the completed 161 kV line, operating at 69 kV. The total demand reached a figure of 3,000 kW.

Due to the distances of up to 15 km. involved between the various structures and tunnel galleries, it was necessary to use a large quantity of equipment and vehicles in order to obtain a reasonable construction schedule. The major part of this equipment was purchased locally or imported in accordance with the foreign-exchange availabilities, and no attempt could be made at standardisation. Very large machine-shop facilities were therefore installed for repair of machinery and manufacture of unobtainable spare parts. The total cost of construction equipment was approximately Cr$100,000,000·00 (US$2,000,000).

* In this article, for comparison, US$1 is taken as equivalent to Cr$50·00.

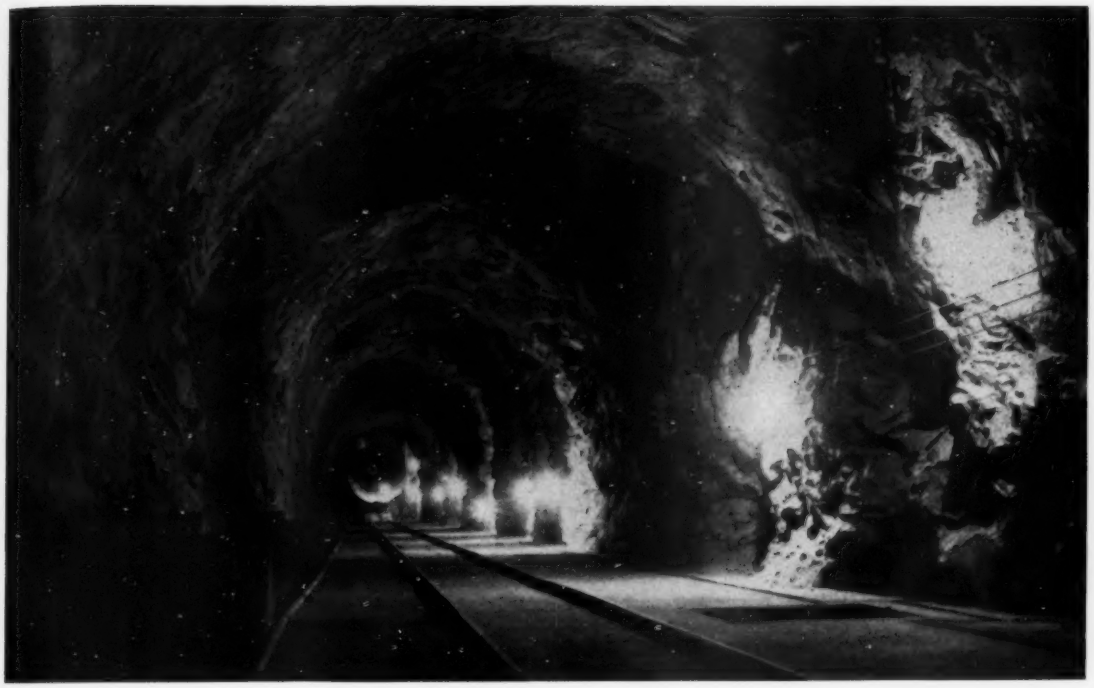

Fig. 9. Looking down the inclined penstock tunnel, a penstock section can be seen at the bottom

Construction Procedure

The most important phase of the work during the first stage was the drilling of the Santo Antonio-Guanhães and Guanhães-surge tank tunnels on a total length of approximately 5,700 m. The Guanhães tunnel, due to its length, was divided into three sections by two auxiliary galleries driven to the tunnel axis permitting the creation of four additional working faces.

The drilling was made by the usual process of having a jumbo mounting 14 to 16 drifters using $1\frac{1}{4}$ in. Coromant type hexagonal steel, and drilling was carried at full section using electrical mucking machines (Conway 75) on the Guanhães tunnel and pneumatic operated muckers at the Santo Antonio (Eimco 21).

Except in a small stretch of about 80 m. where the rock was bad, and required steel support, in general the rock conditions (dry gneiss) were very good, permitting drilling at full section.

The lining was carried out by means of telescopic steel forms fed by a movable mixer-placer set. The invert was poured first and later the upper arch and walls. The equipment for concrete lining was almost entirely built in Brazil to U.S.A. specifications and performed satisfactorily. In spite of all the supply difficulties an average rate of concrete pouring of 350 cu. m. per 24 hours was maintained throughout the operation.

The inclined penstock tunnels were driven from bottom to top using drifter drills mounted on pusher legs.

Another interesting part of the work was the penstock construction. Due to railway clearance limitations only sections with less than 3·00 m. diameter by 3·00 m. length could be shipped already welded. The larger sections were rolled in Rio and shipped in three 1·50 m. wide parts to be assembled and welded at the site. Fig. 8 shows the rolling and welding shop built at the portal of a permanent access gallery leading to the upper part of the penstocks. All welds were tested by X-rays, and in places with space limitations, by gamma rays. A final hydraulic test at 150 m. pressure was carried out upon the completion of the penstock.

The biggest problem during construction was to keep the works adequately supplied, specially with cement, fuel and power. It was necessary to supervise closely the transportation facilities even beyond the normal supply points of Belo Horizonte and the port of Vitoria, as the quantities normally available at these localities were not sufficient to cover the added supply to Salto Grande.

Special trains were organised during the peak of construction and a fleet of trucks was maintained shuttling between Ipatinga and the site.

The civil work was contracted by two local organisations, Custodio Braga Filho and Cia. Alcasan Construtora, jointly, who supplied the greater part of the skilled and semi-skilled personnel. For special work, including the tunnel lining and grouting, the operations were carried out in collaboration with William Schutte & Associates, San Francisco, and Rodio S/A., Brazil.

Assembly, erection, electrical and mechanical work including penstock welding was contracted by Companhia Técnica Internacional.

Erection of the main units, under the supervision of the factory erectors, field investigation, surveying, highway construction and general administration were carried out directly by CEMIG.

(To be continued)

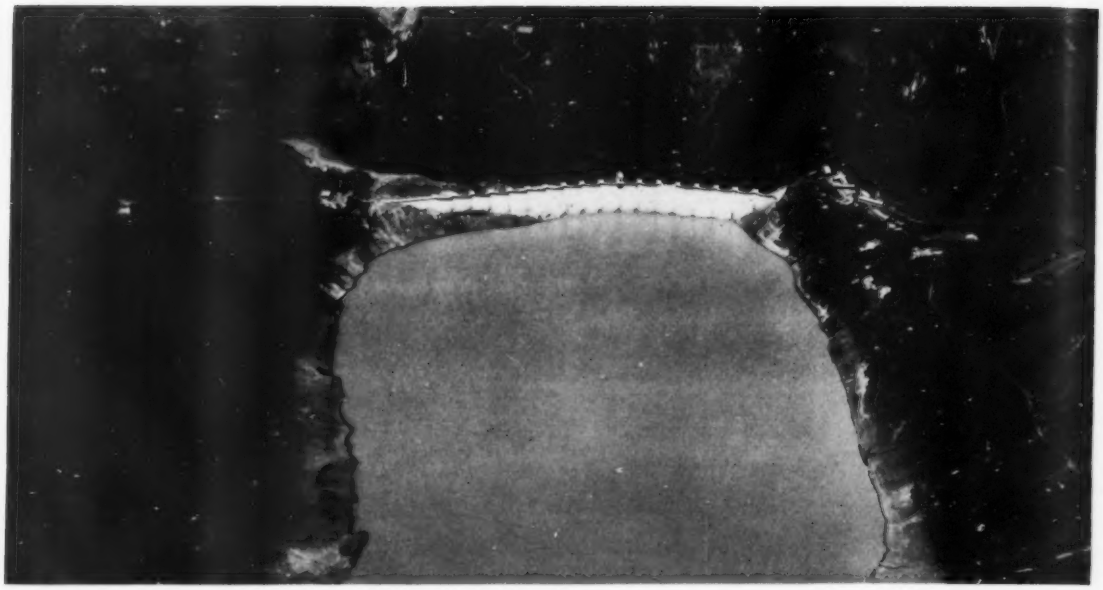

Fig. 1. An aerial view of La Girotte dam

Ground Water in Water Power

George A. Whetstone, Ph.D., Professor of Civil Engineering, Texas Technological College, considers some unusual correlations between ground-water phenomena and possibilities of power generation

IF, in reflecting on the interrelations of ground water and water power, the reader has visualised the utilisation of artesian head or the development in the deep levels of a mine of the head available in the seepage water from higher levels, he will not have been pioneering—such plants have been built and have functioned well. These, however, are not the major applications of ground-water studies in water-power investigations; the power engineer's concern with the subject is usually much more prosaic.

His interest centres first in the group of phenomena associated with the watertightness of reservoirs and the stability of dams. Determinations of probable seepage rates are necessary to estimate water losses due to leakage under or around a dam or into some pervious formation elsewhere in a proposed storage site. Excessive concentrated leakage must be avoided since it may lead to piping and to ultimate collapse of a dam, dyke, or natural embankment. The control of uplift pressures by curtain walls, blankets, drains, or other devices is frequently imperative.

A second category of ground-water questions bears on the regulatory role of the watershed. Bank storage in streams and reservoirs may upset volume calculations based on surface indications alone. Infiltration into valley fill in times of flood may improve low-water flow and may reduce the apparent spillway requirements of a catchment. Moreover, seepage or floods from headrace canals, and land drainage to deeply incised tailraces may affect an agricultural economy by raising or lowering the water table. The evaluation and management of underflow is often of fundamental importance in hydraulic installations in arid or semi-arid regions.

These questions, bearing as they do on nearly every water-development scheme, have been discussed at length elsewhere[1,2] and thus will receive no elaboration here. There remain, however, a number of classes of special circumstances in which ground water becomes the energy-carrying fluid in a hydro-electric development or, at least, where ground water and water power become two closely related factors in a multiple-purpose project.

Power from Artesian Head

In theory, at least, an artesian aquifer is a natural penstock leading water from the elevation of the water table in its outcrop area to a well or spring in its discharge area. Thus nothing should be simpler than to mount a turbine on the well where one customarily expects to find a pump. Quite a few such power plants were reported[3] to be functioning in

South Dakota in 1889 where a hundred wells from 500 to 1,600 ft. deep, flowing under heads of 360 to 425 ft. were utilised in the cities for domestic and fire distribution and for power. A 40 h.p. plant at Yankton drove a mill during the day and an electric-light plant in the evening. The installation was cheaper than a steam plant would have been and the running expenses were negligible.

The inevitable, of course, occurred. As the "penstock" acquired more outlets friction losses increased at the expense of the pressure head.

Power from Mineshaft Water

The Comstock Lode, Nevada's incredible bonanza of which the wealth stimulated the ingenuity of many a confidence man and, also, of many an engineer, was the setting of the most famous power development utilising seepage water. This was a turbine installation, made in 1880, under a 65 ft. head at the mouth of the Sutro Tunnel. Here water which had drained by gravity from the levels above the tunnel, augmented in increasing amounts by water pumped from deeper workings, produced power for mining and milling operations.

The early Cornish pumps on the Comstock, despite their 6,496,400 lb. of moving parts, which included 2·7 miles of pump rods, were unable to keep pace with the water, some of it reaching temperatures of 160° F., which poured into the lower levels[4]. By the time the pumps were finally abandoned (1882) and the workings permitted to fill with water to the Sutro level the pumping installation weighed some 2,700 lb. for every Imperial gallon per minute pumped.

Water-power plants, including what is perhaps the earliest underground station, were instrumental in the reopening of the mines later in the 1880's with centrifugal pumps. These included an installation at the Nevada Mill where a 10 ft. Pelton wheel operating on surface water from the slopes of Mt. Davidson developed 200 h.p. under a 400 ft. head[3]. The tailwater was conducted down a mine shaft in two penstocks to six 40 in. Pelton wheels on the Sutro Tunnel level each of which developed 125 h.p. This plant with its $\frac{5}{8}$ in. jets at 176 ft. per sec. set a new record by utilising a 1,680 ft. head. Two years later a 36 in. Pelton wheel weighing only 180 lb. was installed in another of the Comstock mines under a gross head of 2,100 ft. This wheel, developing 100 h.p. from a half-inch jet, was reported to have an efficiency under its effective head of 1,925 ft., of 85·7%[6].

While the ideal situation for a plant utilising mine seepage water is certainly at a point from which its tailwater can drain by gravity (as in the Sutro Tunnel), at least one coal mine utilised the water percolating into its downcast shaft by collecting it and leading it to a forebay at the head of a penstock. Power developed by a Pelton wheel drove the ventilating fans[7].

Power from Intercepted Underground Streams

Ingenuity has always been a prominent ingredient in French hydro-electric development. Most conspicuous in their penstocks and dams, the trait is also

Fig. 2. Subterranean water supply at Chott Ech Chergui

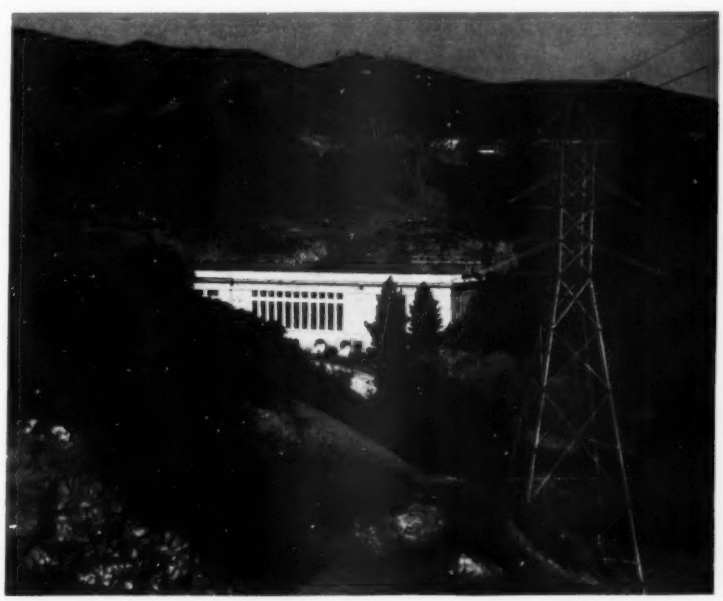

Fig. 3. San Francisquito No. 1 power plant using Los Angeles-Owens River aqueduct water

Fig. 4. Headworks spreading ground conserving Los Angeles river water. This water is reclaimed by pumping, as shown in Fig. 5

exemplified in their diversions. As early as 1925 attempts were made to intercept an underground stream carrying 60 to 360 cusecs at a point in a calcareous massif south of Grenoble some 700 to 800 m. above the spring which was the natural outlet[8]. Two recent issues of WATER POWER[9] have carried abstracts of reports of modern successes with such diversions in the Grotte des Eaux Chaudes and elsewhere in France. While it might require a court decision to determine whether the space under a glacier is actually "underground," the extension of the contributing area to the Lac de la Girotte by means of a diversion dam under Tré-la-Tête glacier on the slopes of Mont Blanc[10] certainly represents a successful venture of a closely related category.

Power from Draining High Ground-Water Reservoirs

While ground water may exist as underground streams in cavernous terrains or under glaciers, its usual occurrence is in a diffused state in very slow motion in the voids of sand, gravel, or some other matrix having only small and tortuous passages between grains. In a few places in the world, such as the High Plains of Algeria and the High Plains of Texas, enormous ground-water reservoirs have accumulated over geologic ages under elevated plateaux in the vicinity of much lower-lying lands. In Texas, land and water laws and soil-fertility patterns are such that the maximum beneficial uses of the water are for irrigation and municipal supply for the land overlying the aquifer. Here the only conceivable justifiable power uses of the ground water are as cooling water for the thermal stations and as make-up water to replace evaporation losses in pumped-storage peaking plants if such are ever installed.

In Algeria, on the other hand, much of the overlying land is in salt flats and the pattern of maximum benefit would seem to involve a diversion of the water from the arid *chotts* to the fertile coastal plain where it would irrigate productive land and permit industrialisation of substantial areas. The project which has received the most thorough study is that of the Chott Ech Chergui[11]. Here, in addition to the improvement of grazing on the High Plains, an ultimate power production of 500 million kWh per annum has been forecast from the fresh water which is to be pumped from under the salt crust of the *chott*, lifted some hundred metres over the crest and then dropped about 900 m. through a series of power plants. Smaller first-step projects have been the subject of detailed engineering studies.

In studies of reservoir silting the suggestion has sometimes been made that a silt-filled surface reservoir might become automatically a ground-water reservoir. In such case, a smaller replica of the Chott Ech Chergui project might be practicable. Careful consideration of silt-particle sizes and the corresponding specific yield of the artificial aquifer would need to be given to each such reservoir to determine the economic feasibility of such last-stand salvage operation. The prospects of such a development seem poor compensation for the damages inflicted by silt entrapment.

Correlation in Multiple-Purpose Projects

The relation between ground water and power need not always be the direct one of the development of power from ground water intercepted at some headwater elevation. An outstanding example wherein both power development and ground-water storage are secondary to the principal purpose of furnishing a municipal water supply exists in the far-flung gathering system of the Department of Water and Power of the City of Los Angeles. While the most publicised

achievement of the department has been the design and construction (together with twelve other cities as the Metropolitan Water District of Southern California) of the aqueduct which brings Colorado River water from below Hoover Dam some 340 miles to the Los Angeles area, fully as much ingenuity went into the development of the other two major sources of supply.

The Owens Valley aqueduct, of which the original 233 mile portion was completed in 1913 and a 105 mile extension to the Mono Basin was finished in 1941, intercepts streams flowing off the eastern slope of the Sierra Nevada which formerly drained to salt lakes in closed basins. Aqueduct delivery is equalised by storing flood waters in underground reservoirs by spreading on porous areas in the Owens Valley and then retrieving the water by pumping much in the manner of the Chott Ech Chergui project. Some surface reservoirs above and below the major power stations provide for daily pondage, thus allowing the hydro plants to operate on peak demands.

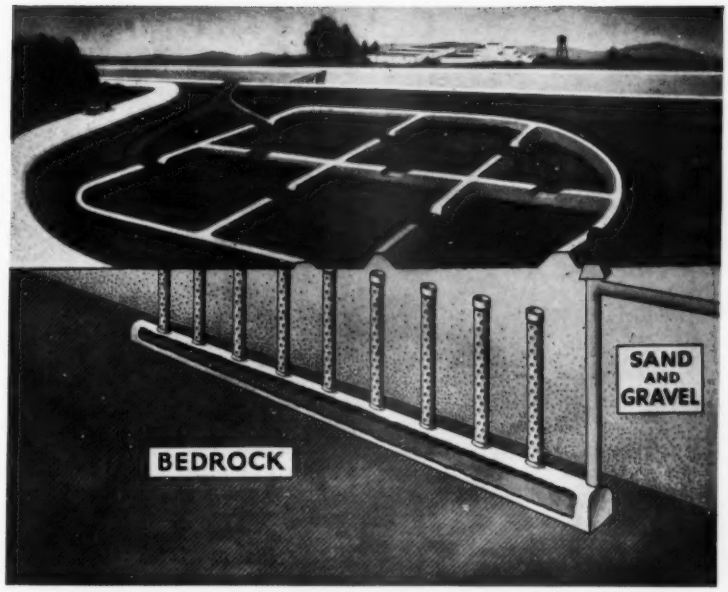

Fig. 5. Diagrammatic view of infiltration ground below headworks spreading ground, showing method of recovery

Several spreading basins have been developed in the foothill area just north of the city to permit storage of the total flow of the Los Angeles River, the greater portion of which is usually underflow rather than surface flow except in times of floods. By recharging or pumping Los Angeles River water as dictated by the fluctuations in supply and demand, the delivery rates of the Owens and Colorado aqueducts may be kept reasonably uniform throughout the year. An obvious analogy exists between this three-source water supply and a power system of three plants—two with seasonal storage at considerable distance from the plant and ponds near the plant, and a seasonal pumped-storage facility. It would also be feasible to recharge some aqueduct water to underground storage in or near Los Angeles if changes in the demand were to make this operation desirable.

As other users contemplate seeking water supplies at points ever further afield the possibilities of effecting major economies through power developments along the aqueduct and through storage in underground reservoirs at or near the downstream end of the water transmission line will bear careful study. The world has few Chott Ech Cherguis and even fewer artesian areas with power potentialities of economic interest, but it has many projects in which an ingenious appraisal of underground storage, pumped storage, and interception possibilities may enhance the feasibility materially.

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Gasser, J. "Chott Ech Chergui," *Encyclopédie Mensuelle d'Outre-Mer* v. 1 (1950), p. 32-34.
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Cathodic Protection. A folding leaflet from F. A. Hughes & Co. Ltd., Devonshire House, Mayfair Place, Piccadilly, London, W.1, gives particulars of the "Guardion" cathodic protection system for the protection against corrosion of buried and submersible structures.

Energy from the Sea

During June of this year an important conference was held on tidal energy, in Paris and in St. Malo, by the Société Hydrotechnique de France, and was attended by some 200 engineers from many countries

PART ONE

WHILE the conference contained some remarkably interesting papers on a wide variety of topics connected with the possibilty of extracting commercial amounts of energy from the sea, the most important aspect of its work was that of providing an opportunity for learning the full details of the world's first tidal power project, on which work has now commenced.

This project involves the erection of a tidal barrage across the mouth of the River Rance where it enters the sea near the port of St. Malo; and it was therefore appropriate that the first part of the conference should take the form of visits to the tidal model at St. Malo itself and an inspection of the site of the dam. The preliminary stages of the civil engineering work were also, of course, on view.

Touching on the papers in greater detail it is perhaps appropriate first to give a brief description of the Rance project. The dam is to be situated about 2·5 km. to the south of St. Malo, between the Pointe de la Briantais and the Pointe de la Brebis. The basin so enclosed, which reaches back as far as Dinan, has a surface area of about 20 sq. km. at high tide.

The dam will be 710 m. (2,329 ft.) long and 48 m. (157 ft.) wide. The height of the crest above the highest tide level will be 1·5 m. (4·92 ft.). The most interesting feature of the project concerns the type of generating unit to be employed. This takes the form of the totally submerged upstream bulb type, there being 38 generating units in all, each of 9,000 kW capacity and immersed in orifices in the dam. The centre line of the sets are 5·5 m. (18 ft.) below low-water level so that the units are always completely immersed. The upper part of the dam is hollow and will contain the control gear, switchgear and other ancillary equipment. Double carriage-ways will be available at the top of the dam, thus forming a much-needed bridge across the river. The dam will also contain a number of sluices, while on the west bank there will be locks for the use of the vessels navigating the river to Dinan.

A factor which renders the Rance scheme of the greatest possible technical interest is that which relates to the method of operation. In all previous tidal power projects (including the Severn Barrage scheme, the subject of a paper at this conference) no proposals have been put forward for schemes for generating power at other than the intermittent periods when the tide provides a difference in level between the impounded water in the estuary and the tide level outside the dam. The extremely ingenious solution to the problem of providing tidal power at practically all times of the day investigated by Electricité de France, and now to be put into practical operation, hinges on a combination of tidal power generation and pumped storage.

It was not possible to consider such a scheme until the designers of water turbines had produced a unit which could operate both as a pump and a turbine under variable heads, and which could generate or pump with the water flow in either direction. As will be seen later in these notes, this problem has been the subject of research and experiment by French designers for a number of years, and after tests with machines of this type in different conditions, it was decided that sufficient experience had been gained to warrant the inauguration of the Rance scheme.

The method of operation is as follows: assume first that high-tide level exists on both sides of the dam. If energy can be borrowed from the supply system for pumping purposes it is possible to raise the level within the estuary by turning the generators into pumps; as the tide falls away outside the dam a head becomes available which is obviously greater at any given state of the tide than would have been the case if pumping had not taken place.

Generation can start as soon as the minimum head is available; this period in relation to the tide occurs sooner than would have been the case if pumping had not raised the head within the estuary. Generation continues until sufficient water has been evacuated from within the estuary to reduce the head to minimum generating levels. The turbines, with their feathering blades, have the additional advantage that they can be turned into valves, allowing a flow of water for each turbine of 180 cu. m. per second under a head of 1 m., as compared with the valves themselves which allow for a flow of 420 cu. m. per second under the same conditions.

By turning all the 38 turbines into straight-through valves and also opening all the sluices, the water within the estuary can be rapidly evacuated at about the time of low tide. The units being totally submerged, it is possible, when all the water that can be evacuated under gravity flow has been removed, to pump out further water again if energy for pumping is available. That is, if this period, in relation to the tide, is an off-peak period.

By this reverse pumping operation it becomes possible to produce an artificially low water level within the estuary; and as the tide rises on the outside of the dam again a generating head is reached earlier, in relation to the tide, than would have been the case if the water level had not been artificially lowered.

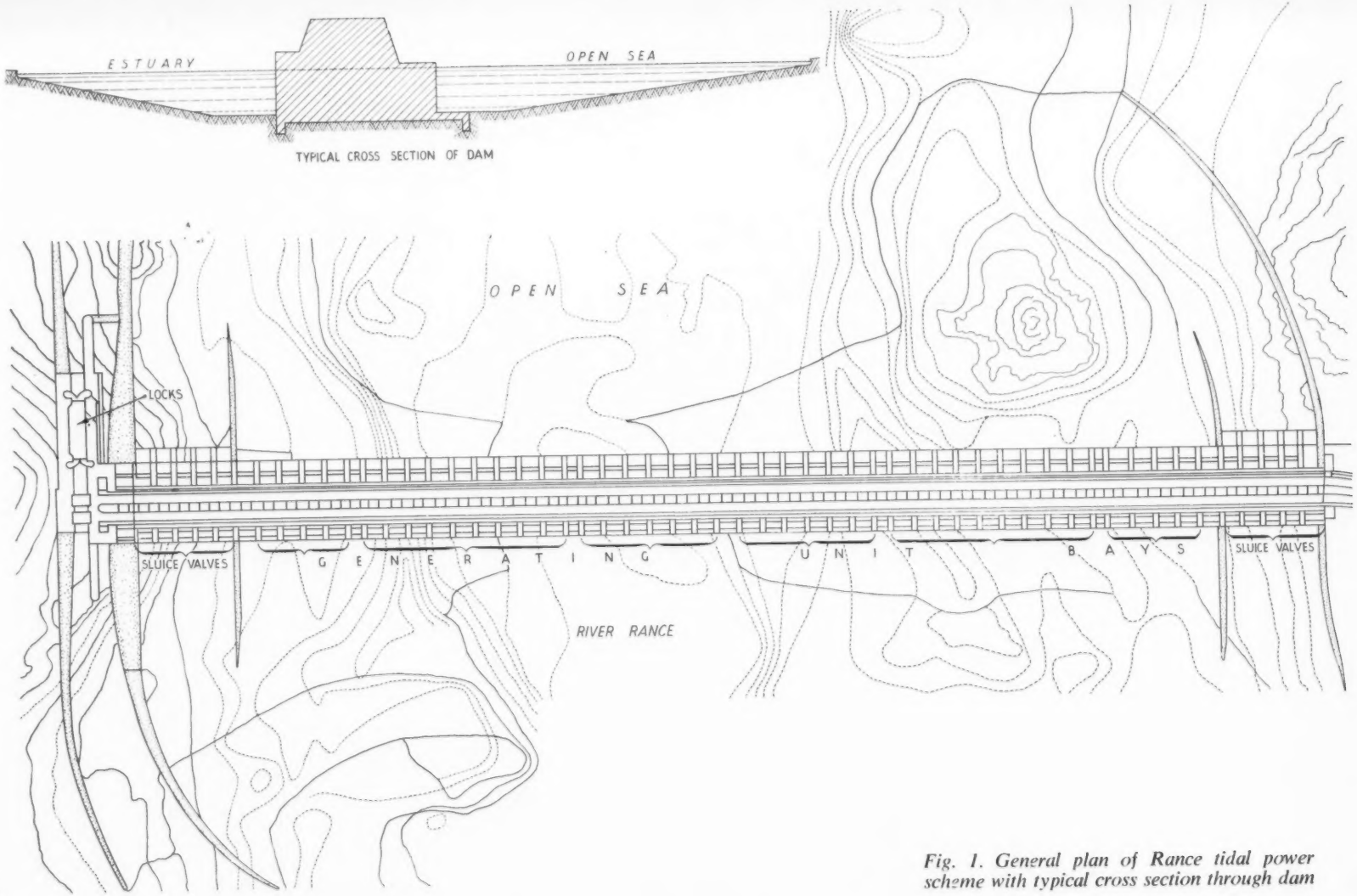


Fig. 1. General plan of Rance tidal power scheme with typical cross section through dam

As the tide continues to rise generation takes place until sufficient water has flowed into the estuary to destroy the minimum generating head. The turbines are again turned into straight-through valves and the sluice valves are opened, thus allowing rapid inflow of water until high tide is again reached. The cycle can then recommence.

The most important feature of the method of operation indicated above is that the cycle is capable of almost infinite variation, so that in effect tidal power can always be made available to the system operator at the same time he most needs it—the peak period. For example, if the commencement of the cycle outlined above, with high tide level both sides of the dam, should coincide with the system peak, arrangements could have been made for pumping during the preceding off-peak hours so that when the water was at high tide level outside the dam it could be lowered within the basin to such an extent that generation would be possible with water flowing, this time, from the outside to the reservoir. The same variable features apply to the low-tide period, and indeed it is claimed by the authors of the various papers describing the scheme that pumping energy can be usefully utilised at almost any time in relation to the tide, in order that generation may be possible when most needed.

The 38 generating units will have a total capacity of 342 MW, and the annual output of the scheme will exceed 800 million kWh in excess of the energy borrowed for pumping purposes The project, which is estimated to cost £35 million, will be in full commission in 1960, and it is estimated that when compared with a hydro-electric station of the run-of-river type, its power to economise in the use of coal is equivalent to 1,000 GWh per annum.

The Rance scheme, on which work is actually in progress, is intended to serve not only as a practical power-producing plant to provide a substantial contribution of energy to the French network, but also as a pilot scheme for other and larger tidal-power proposals.

One such scheme which was discussed at the conference, and whose site was inspected by your Correspondent, was that which relates to the enclosure of the Baie du Saint Mont Michel, also on the Brittany coast and adjacent to St. Malo. Here a gigantic dam with a total length of 23·4 miles is proposed, to enclose a basin of between 700 and 800 square kilometres at high tide level. The proposal is for a dam containing no less than 1,200 generating units (each of a capacity of between 7,000 and 10,000 kVA) to run out due north from the Pointe du Groin to the archipelago of islands known as the Iles de Chausey, and then for a second dam to run due East back to the mainland at Cotentin, just North of the town of Granville. The power station dam would be made up of 400 caissons, containing generating units, sluices, transformers, and ancillary equipment. The capacity of this enormous project is estimated at between 8,000,000 and 10,000,000 kW, with an annual production approaching 25 milliard of kWh, which is about half of the present amount of electrical energy consumed in France. The method of operation proposed is the same as that outlined above for the Rance project, that is to say, with variable cycles of pumping and generating. If this scheme comes to fruition, it is expected to take 15 years to complete.

With this brief outline of the tidal power projects on the Brittany coast, it is proposed now to amplify the account of the Conference by touching in rather greater detail on some of the papers presented. The fourth section of the Conference dealt with model tests, and the very large tidal model at St. Malo was inspected by the delegates. In the general report on this section Mons. Vantroys said that engineers are continuing to seek more and more information from models made for hydro-electric purposes; for example, infiltration flow, not only in regard to layering effects but also in regard to turbulence, needs to be studied, while the phenomena of the transport of solid matter in suspension requires much greater research. Thus the models on which the tidal power project had been based were considerably more elaborate than those applicable to other projects.

In a paper dealing with the use of hydraulic models, Mons. G. Mauboussin, of Electricité de France, describing the Rance tidal-power project, stated: The Rance dam will be built between the Pointe de la Briantais on the right bank and the Pointe de la Brebis on the left bank at about 2·5 km. upstream from St. Malo. From this point the width of the estuary is 800 m. at the level of the highest tides. In the centre of the river the depth of the water varies between 12 and 25 m. according to the amplitude and the hour of the tide. (See Fig. 1.)

The barrage will be made up in the form of a hollow dam in reinforced concrete, in the interior of which there will be 38 generating units each of 9,000 kW which can operate either on emptying or filling the basin, and either as turbines, pumps, or simply as orifices. (See Figs. 2 and 3.)

In addition, 10 large sluice valves will be arranged with five on the right bank and five on the left bank. These valves operate against full water head and will ensure, during the operation of the power station, complete emptying of the reservoir or complete filling at high tide. It will be seen that they will be of great assistance during the execution of the constructional work.

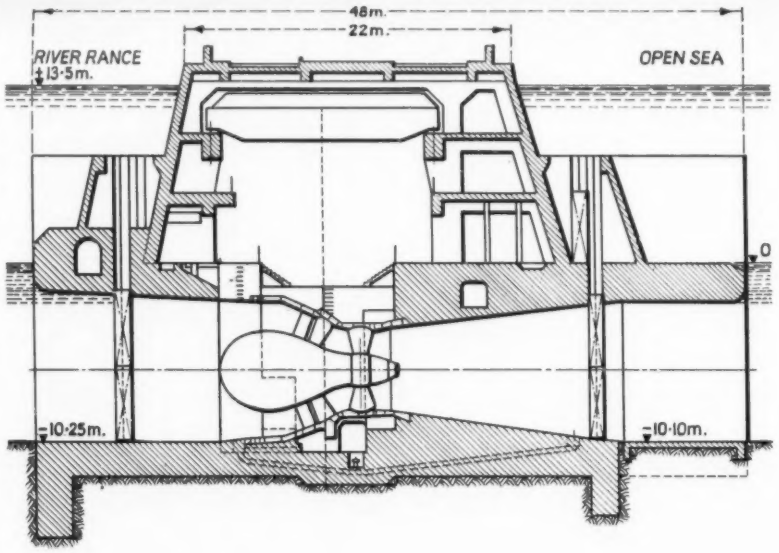
The project includes all the locations necessary for the installation of high-voltage transformers as well as control equipment and the auxiliary services for the power station. Access to the machine room is gained by an inclined roadway on the right bank. Boats will be able to pass through the barrage by means of a lock on the right bank.

Characteristics of the Site

The Bottom of the River and the Banks. At the site of the dam, the bed of the river Rance is composed of granite, lightly broken up on the surface and covered by a layer of alluvium in the form of sand and pebbles which in places reaches several metres in thickness. It does not appear possible that the contractors will encounter any appreciable geological faults. A large number of soundings (with cores taken at frequent intervals) have been carried out during the last few years. Piles have been driven for test purposes, and have penetrated for some distance into the rock.

The granite rocks on the bank, at the Pointe de la Briatais and the Pointe de la Brebis, form supporting points which will be entirely satisfactory for the ends of the dam.

The Tidal Range. In the region of St. Malo and the



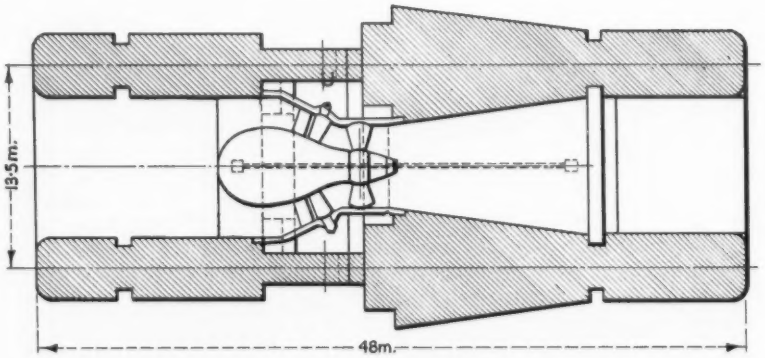
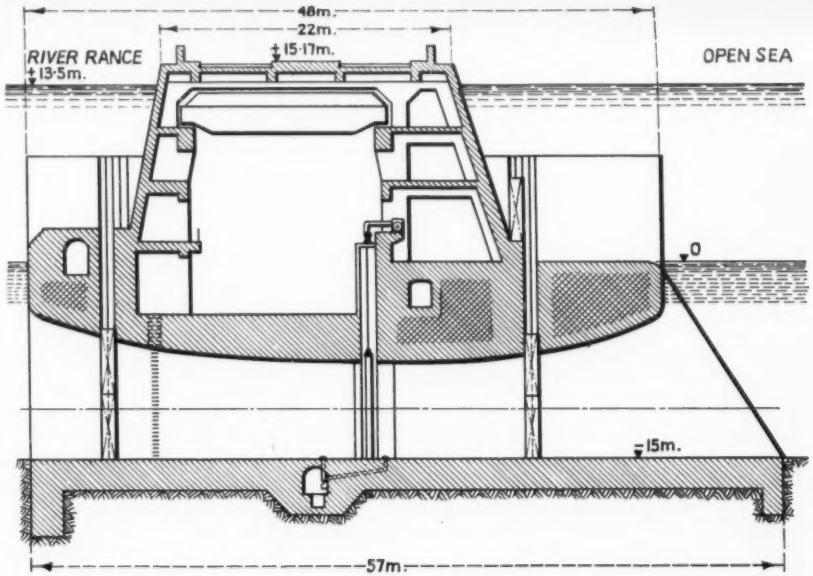


Fig. 2. Cross sectional diagrams showing elevation and plan showing general arrangement of generating unit



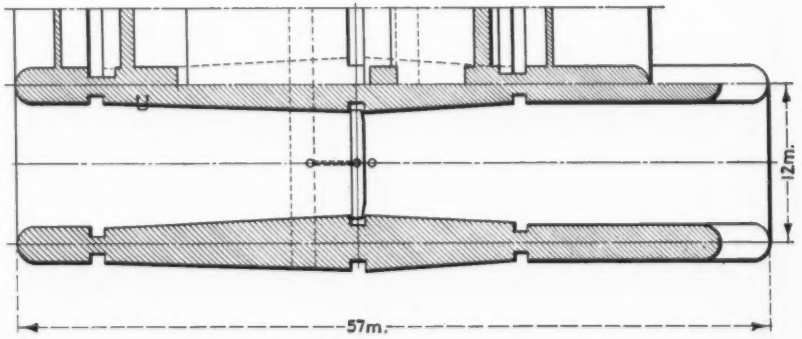


Fig. 3. Diagrams showing cross sections through one of the sluice ways

Baie du Saint Mont Michel the tides have very large amplitudes, and this is largely due to the topography of the coast line near Cotentin. The difference of level between high tide and low tide reaches 13·50 m. (about 44 ft.) at exceptional tidal periods, when the tide has a coefficient of 120 (compared to normal high tide of 100). The tidal range is 10·9 m. (36 ft.) at spring tides with a coefficient of 95, 8·45 m. (29 ft.) with average tides of coefficient 70, and is even 5·40 m. (18 ft.) at ebb tides with a coefficient of 45. Fig. 4 shows how the tides vary in the course of a year; it also shows clearly the brief period which separates two tides of a high coefficient—for example 95%—and this feature of the tidal cycle will have a considerable influence on the speed at which certain parts of the work will be carried out.

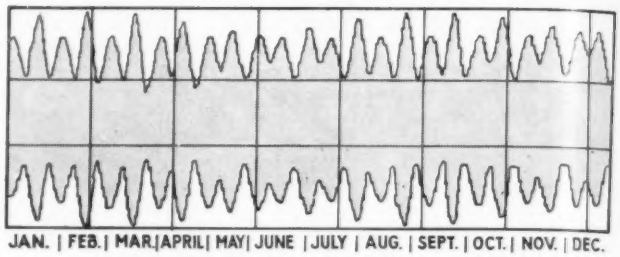


Fig. 4. Daily amplitude of tides during the year 1957

According to the rise and fall of the tides, and the filling or emptying of the estuary, currents will be created the speeds of which, at the site of the dam, are indicated on Fig. 5. The instantaneous flow measurement reaches 15,000 cu. m. per second at spring tides. During the carrying out of the work the speed of the current, which at the present time is of the order of 2 m. per second with a tide of coefficient 95, will increase considerably in proportion to the rate at which the presence of the various structures reduces the passage left for the ebb and flow.

Construction of the Works

The method envisaged for the construction of the dam is that all the structures shall be made under dry conditions, within successive coffer dam enclosures.

Normal Coffer Dam Work. The construction of the normal type of coffer dam with a transverse section as shown in Fig. 6 will necessitate the following operations:

(i) The immersion of rocky material to provide an underwater dam of a height equal to about $\frac{1}{3}$ of the height of the coffer dam.
(ii) The driving into this dam of two screens of piles, these being parallel and connected together by tie-rods.
(iii) The filling with sand of the space between these two screens.

The spacing of the two screens will be a function of the height of the coffer dam.

Transverse partitions made up of piles are envisaged every 60 m. In order to ensure sufficient footing at the foot of the higher piles, the slope of the base will be reinforced with miscellaneous material. If later the coffer dams become affected by high-speed currents, the external slopes of the bank will be protected by rocks of such a size that there will be no risk of their being carried away.

The rocks submerged to make up the under-water dam will have to satisfy two conditions which are apparently contradictory. They must be small enough for the piles to penetrate between them, and large enough not to be carried away by the currents which exist at the time they are immersed. The first of these conditions has been satisfied by choosing material of a maximum weight of 5 kg. per piece, with a diameter of 15 cm., even though the piles could be driven through a thickness of 7 to 8 m. of material of 10 to 15 kg. per unit weight. It will probably be necessary in certain particular cases to use material having this larger weight for the upper part of the dam.

As the first condition could be satisfied in this way, it remained to determine the speeds of current at which it would be possible to construct coffer dams of this type. Tests made on the model, which will be described later, have enabled the second condition to be satisfied also.

Special coffer dam for the closing section. A moment will arrive during the progress of the work when the opening left for the passage of the sea will become so narrow as to cause currents which could not be resisted by the rocks used for the under-water dams. It is thus necessary to consider other arrangements for the actual termination of the closing of the river Rance. It was first envisaged that a permeable closing section might be designed, using a dam (C_1 Fig. 6) of larger and larger rocks, this work being carried out during a period of average or small tides. It was assumed that with the current reduced by the dam C_1, it would be possible to construct a counter dam C_2 and fill the space between them with small material such as sand and pebbles, into which a screen of piles could easily be driven.

Tests on the model enabled the dimensions of the rock and the volume necessary for the construction of the dam C_1 to be determined. At the same time, as a result of systematic tests, an idea could be gained of the size of the filtration flow through the dam C_1; —information extremely useful in relation to the operations to follow, including the establishment of the counter-dam C_2 and the driving of the piles in the core between the two dams.

Number of Enclosures. Two points were considered in regard to investigating the optimum number of enclosures:

(i) The need to utilise to the best advantage the material to be extracted from the excavations, in order to limit the quantity needed from quarries.
(ii) To reduce in every possible way the dimensions of the rocks, in order to facilitate the placing and later removal of this material.

This second point required the reduction of the speed of current, and thus of minimising the difference in level between one part of the work and another. For this purpose it is necessary to have the sluice valves and some of the orifices for the generating units available as soon as possible.

These considerations led to the planning of enclosure I on the left bank as the first move, and within this enclosure the locks and the 5 sluice valves on that side will be constructed. Then enclosure II on the right bank will be made, using material extracted from the excavations carried out within enclosure I.

In this second enclosure there will be constructed the 5 sluice valves on the right bank and 9 orifices for generating units. The enclosure II, which is very large, enables the complete removal of the small island of Chalibert under dry conditions, and thus this work will be carried out economically, and will enable the greater part of the rock for the closing operation to be derived from the actual site.

There will remain a breach of about 310 m. between enclosures I and II and this will be reduced to 180 m. by constructing coffer dams of the normal type, bearing in mind that all the sluice valves and 6 of the generating unit orifices will be ready at that time.

It will then be necessary for enclosures I and II to be completed as regards the civil engineering work, and for the demolition of the north and south coffer dams N_1S_1 and N_2S_2 to be completed before the actual closing operation can take place.

It was not thought desirable to provide two successive enclosures between the enclosures on the banks. This would have delayed the work and also would have needed the construction of a transverse coffer dam of considerable height. In consequence a single central enclosure will be provided, joining the lateral coffer dams A_1 and A_2 first by a north coffer dam of 130 m. of normal dam construction, and then 180 m. of special dam design for closing, and then by a southern coffer dam easily built in calm water.

It should be noted that from the time the northern closing section is completed, that is to say from the

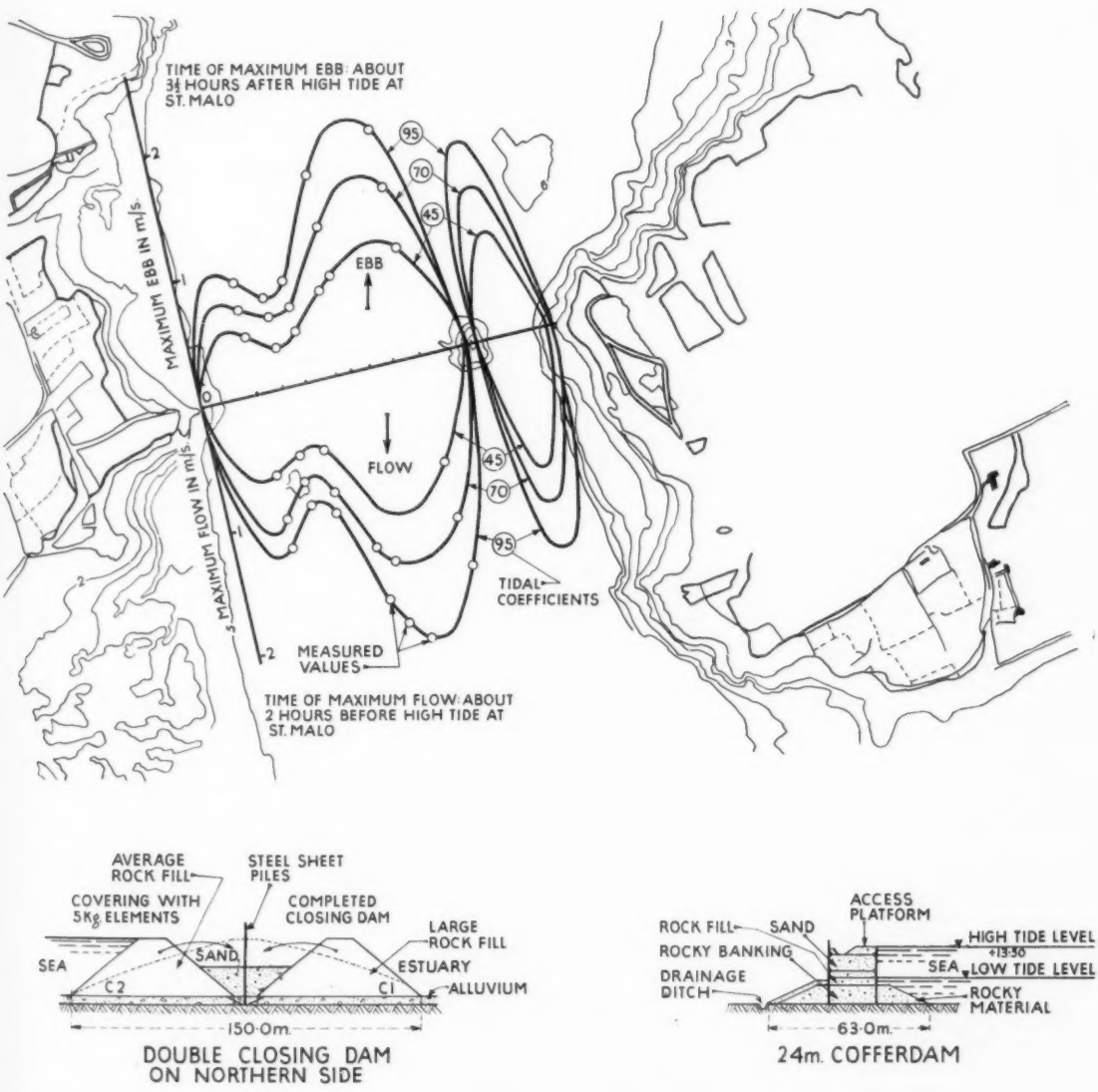


Fig. 5. The diagram above shows the speeds of the currents in the vicinity of the barrage; the curves indicate the maximum speeds for tide of coefficients 95, 70 and 45 along the line of the barrage. The inset diagrams below show the methods to be adopted for constructing the cofferdams

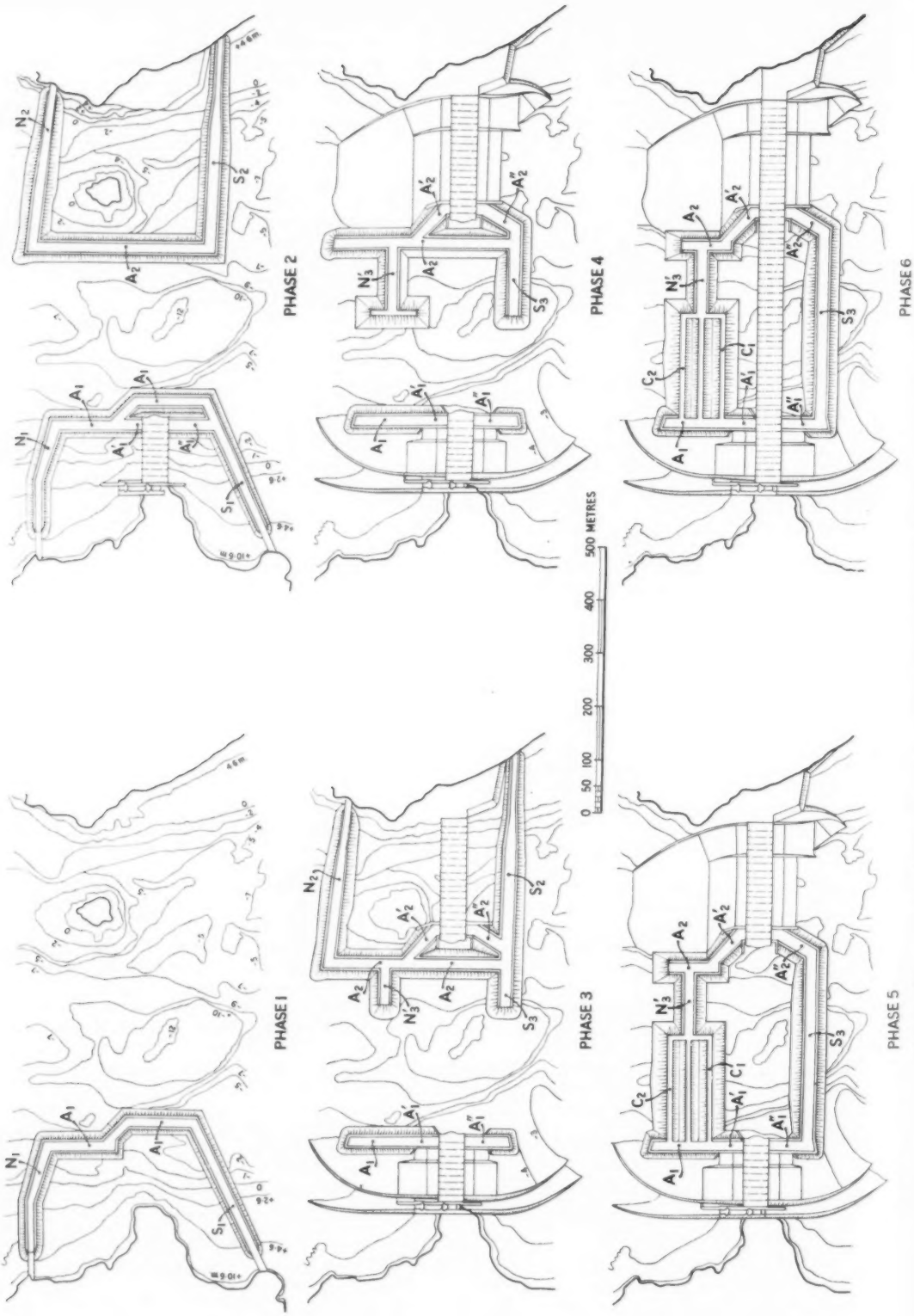


Fig. 6. Diagrams to show sequence of operations projected for the constructional work

time that the estuary has been isolated from the sea, the first generating units can be placed in service.

The programme provides for the commissioning of the first units at the end of four years, and for the remainder of the work to be completed in a further two years.

Construction of the Normal Type Coffer Dam. Two problems were posed by the construction of the normal type coffer dam for this project.

First, it will have been seen earlier that the weight of rock envisaged for the under-water dam was 5 kg. per unit. It was thus a question of finding miscellaneous material the largest elements of which did not exceed 5 kg. It was necessary to decide on the granular composition of this type of material. For the tests the following composition was assumed:

20% of material with unit weight between 5 and 2·5 kg.

30% of material with unit weight between 2·5 and 0·75 kg.

40% of material with unit weight between 0·75 and 0·1 kg.

10% of material of unit size smaller than 0·1 kg.

It was also mentioned above that in certain cases it was desirable to make up the upper part of the under-water bank with elements having unit weights of 10 or even 15 kg. The granular composition of material for the tests in relation to this aspect of the work was assumed to be as follows:

35% of material with unit weight between 15 and 8 kg.

25% of material with unit weight between 8 and 5 kg.

40% of material with unit weight between 5 and 2·5 kg.

The tests consisted in determining, with the aid of a "distorted" model representing the whole of the Rance on a scale of 1/80-1/500, the maximum level changes near the structures for various tides and for various phases of construction; and then, on a model canal of 1/40 scale, the investigation of the weight of material for the under-water bank which would stand up to each maximum level change. This was done by circulating water at a rate corresponding to each change in level during 20 minutes.

TABLE I

Number of sluice valves in service	Possible residual breach	
	Under-water bank with 5 kg. material Metres	Under-water bank with 15 kg. material Metres
0	400	275
5 sluice valves	300	250
10 sluice valves plus 3 generating unit orifices	250	165

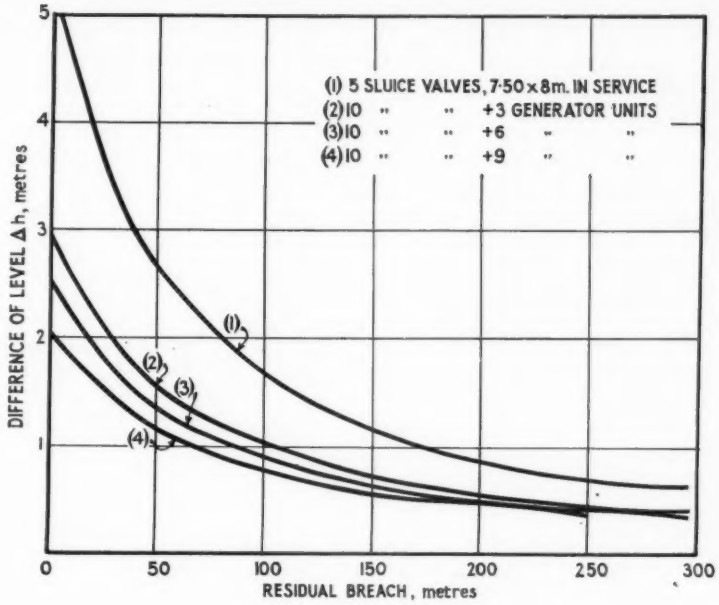


Fig. 7. Tide coefficient 95

The results are shown in Table I, and relate to a tide with a coefficient of 95, this being typical of the tides found approximately every month throughout the year.

With an average tide of coefficient 70 the work could progress considerably further, and thus with 10 sluice gates and 3 generating orifices the breach could be decreased from 165 m. to 90 m., with 15 kg. unit weight material.

In the light of these results it has been arranged that the coffer dam may be carried on until there remains only a breach of 180 m, leaving the protection of the under-water bank to be carried out by a covering of larger rocks in order to cope with tides of a coefficient greater than 95.

There was also a second aspect of constructing the normal type coffer dam which had to be investigated. It was envisaged that the enclosure II would be commenced on the right bank by starting with the transverse coffer dam I_2, using two points of attack beginning from the middle of A_2, one directed towards the north (i.e. towards the sea) and the other towards the south. The working front would thus be attacked by the ebb or the flow. On a complete undistorted model of the river Rance, to a scale 1/150, the fields of operation of the currents in this region were investigated and it was found that it would be necessary to retain the northwards direction for the branch of the coffer dam A_2, directed towards the sea, but that it would be preferable to incline the southern branch by about 15° towards the east.

The frontal attack by the current on the coffer dams in course of construction would lead to a scouring at the foot of the sheet piles at certain tides, where the banks were made up of elements of unit weight of 5 kg. These scouring actions, if they were serious, could be entirely prevented by placing on the under-water bank a permeable steel gabion to deviate the current.

Construction of the Closing Dam. In regard to the construction of the permeable dam C_1, 180 m. long, it should first be realised that there will be available for the passage of the sea water 10 sluice valves and 6 generating unit orifices. The planning of this part of the work has been carried out by the aid of two models representing the whole of the river Rance. The first model, which is the oldest, is the distorted model (scale: 1/18-1/500), and with its aid it was possible to investigate differences of level (Δh) at flow and ebb of the tide for various tidal conditions and for various widths of the breach. It should be noted that on this model the breach dimensions were limited by the vertical height.

The graph in Fig. 7 shows, for a tide of coefficient of 95, the considerable reduction possible for differences in level, according to the number of sluice valves placed in service.

On a canal made to a scale of 1/40 the various differences in level drawn from the distorted model were reproduced, and thus the weight of material needed to resist these differences in level was determined.

With this information available, it becomes possible to determine with sufficient precision the type of rock to be employed for carrying out the closing operation, according to the period when this work was contemplated.

On the second undistorted model recently constructed at St. Malo, to the scale of 1/150, the whole of the estuary of the Rance up to the lock at Chatelier is represented, and tests have been made to show that the closing operation could be carried out under the above conditions. In making this test, a period of 15 days from the 5th to the 24th of June 1957 has been chosen. During this period the tides will be somewhat small, and after the 24th of June there will be several days during which the amplitude still diminishes, thus giving a margin of security and preventing any incident from occuring. To enable the closing operation to be carried out in 15 days, it is obviously necessary for a very large amount of material to be made available. This requires a large amount of plant, for example two belt conveyors each capable of a flow of 6,000 tons of material every 24 hours; but it seems that it is absolutely essential for this provision to be made if there is to be no risk arising from a tide of a very high coefficient occuring unexpectedly during the course of these operations. The weight of the rock to be dealt with has been closely defined in relation to the measure of progress made on the work.

This test was carried out in an uninterrupted run during 30 consecutive tides, thus requiring 30 hours on the same time scale on the model. The material was regularly tipped into the water with the aid of small model conveyor belts. It demonstrated that it will be possible to carry out the closing operation with the materials as envisaged—15, 30, 50, and 70 kg. It is also shown that the progress of the work is very fast at first, and this is explained by the fact that average figures were taken in the calculations whereas the bed of the Rance is not strictly horizontal and the dam is at its minimum height at the extremities. It was also found that from the 15th tide, the progress was slower than had been envisaged for the same reason. Finally, the closing operation on the model was carried out a little sooner than had been anticipated, being complete by the 27th tide instead of the 30th.

Monsieur Mauboussin's paper concludes with a short section on the filtration flow through the closing section of the dam.

(To be concluded)

M.V. Switchgear for Snowy

The first switchgear for voltages over 300 kV ever ordered in Great Britain is to be made by Metropolitan-Vickers Electrical Co. Ltd., Trafford Park, Manchester, for the Snowy Mountains hydro-electric scheme in Australia. The order, which is worth £125,000, was obtained by M.-V.'s associates in Australia, Electrical Industries Pty. Ltd., in the face of severe Continental competition.

The new switchgear will consist of five 330 kV Metropolitan-Vickers air-blast circuit breakers, type GA11W8, rated at 1,200 A and having a breaking capacity of 10,000 MVA, together with the necessary compressor plant and eighteen 330 kV outdoor current transformers (with multiple secondaries). It will be installed in an outdoor switching station, 4,500 ft. above sea level, near the T1 underground power station of the Snowy Mountains Hydro-Electric Authority. The power-station output of 320 MW will be stepped up by transformers to 330 kV and fed to the T1 switching station, which will be equipped with the five breakers just ordered. These will be connected by 100-mile long transmission lines to substations in New South Wales and Victoria, which will feed the existing power systems of the Electricity Commission of New South Wales and the State Electricity Commission of Victoria; future 330 kV lines will be extended to Sydney and Melbourne as the load demands.

The five MV circuit breakers, which are due for commissioning during 1958, will complete the first section of the switching station, but a twelve-breaker station to be known as the T1/T2 station is ultimately envisaged.

A.E.G. Progress. Allgemeine Elektricitäts-Gesellschaft of Berlin and Frankfurt-on-Main have published an admirably produced brochure which describes their activities during the last two years. In this period they have carried out eighteen major power schemes including the installation of hydro-electric plant in countries as far afield as Finland and Spain. Also of interest to water-power generation is the work they have done on high-voltage transmission lines and transforming equipment.

Crane/Excavator. A pamphlet from Blaw-Knox Limited gives a specification of the BK-Fifty half-cubic-yard excavator which can be adapted as a lifting or grab crawler crane. Independent power boom hoist and power hook lowering features are optional additions.

Hunting Technical Services Limited, of London, have issued a coloured brochure to call attention to the work they are doing with their aerial survey and mapping organisation, and although this publication is concerned primarily with food production and the discovery of new mineral deposits the technique they use has an obvious application to hydro-electric development, especially in the more remote parts of the world.

138 kV Cables for Vancouver Island

The mainland of British Columbia has an abundance of power resources but the neighbouring Vancouver Island is not so fortunate and its supply problems were becoming acute. Mr. Tom Ingledow, at that time Chief Engineer of the British Columbia Electric Co. Ltd., conceived the idea of solving these problems by means of a power link from the mainland to Vancouver Island. The total length of such a link is less than 50 miles, but includes a number of sea crossings, the major one across the Strait of Georgia being approximately 14 miles. The question to be solved was, could a high-voltage submarine cable capable of supplying sufficient power be made and laid? A preliminary approach was made to the British Insulated Callender's Cables Group who had been actively interested in submarine cables for some time and were engaged in investigations for the Central Electricity Authority relating to the proposed Cross-Channel power cable. Ultimately this firm put forward positive proposals, resulting in their being awarded an order worth approximately three and half million dollars for the supply and installation of some 91 miles of high-voltage single-core submarine cable.

On the mainland network, high voltage power is transmitted at 230 kV, whereas on the Island it is transmitted at 132 kV. It was decided that the power carried by the cable link, 120 MVA, should be transformed down from 230 kV to 138 kV on the mainland and fed to the link at the lower voltage.

Long lengths of submarine cables capable of carrying high power had already been made and laid elsewhere but these cables had all required large numbers of joints in the conductors, insulation and sheathing, introducing potential sources of weakness. The most desirable form of cable, therefore, was one that could be made in one continuous length without any joints. The most satisfactory solution to this problem was to use the single-core gas-filled pre-impregnated paper-insulated type of cable with which the BICC Group have been associated for some years and which had already given a very satisfactory service on land. For land service these cables are usually operated at 200 lb. per sq. in. pressure. However, at the maximum depth at which the cable would be laid the external pressure on the cable would be as great as 280 lb. per sq. in., so that to guard against the results of external damage to the cable sheath the internal gas pressure had to be greater than this figure. Therefore, an internal gas pressure of 300 lb. per sq. in. was decided upon. The subjection of parts of the cable to these high pressures made a hard compact form desirable. Thus, instead of following the normal practice in single-core gas cables of having a slight clearance under the lead sheath to facilitate gas flow, the cable was designed to have the sheath a tight fit on the core and to have a central gas duct in the conductor. The use of a duct of purpose-designed dimensions, together with a dielectric of pre-impregnated paper, having little surplus compound, would also enable predetermined uniform gas-flow properties to be achieved.

As finally produced, the 0·35 sq. in. conductor consisted of a central spiral steel duct, over which were applied two layers of copper wires and a conducting screen of three impregnated metallised paper tapes. Pre-impregnated paper tapes were applied over the

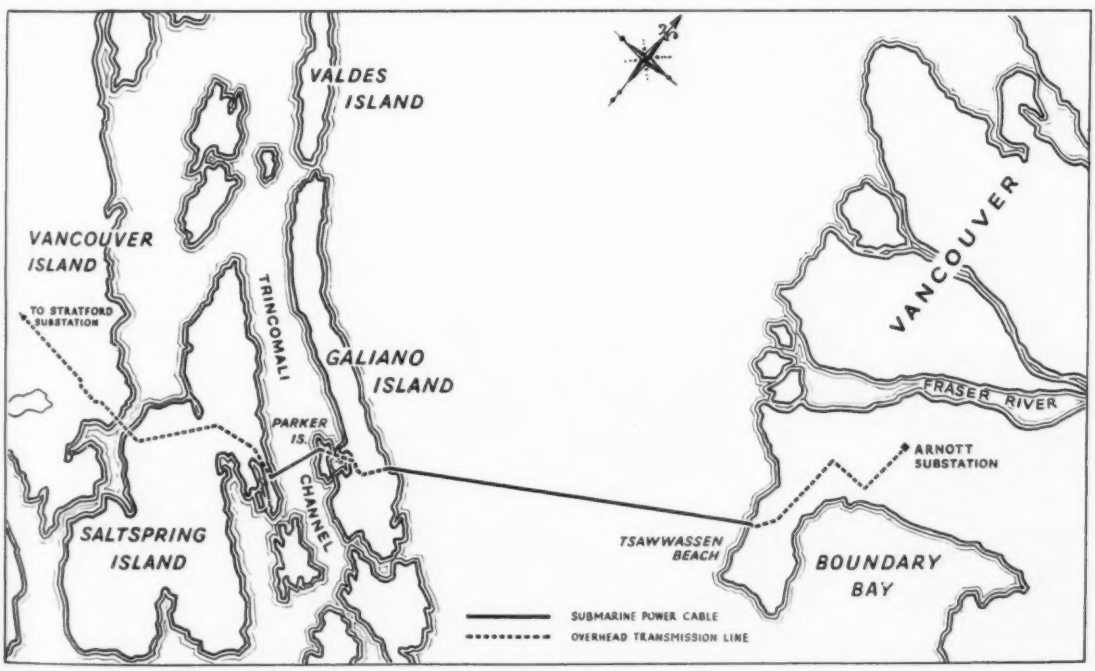


Fig. 1. Map showing route of power link between Vancouver Island and Canadian mainland

Fig. 2. Stepped sample of 138,000 V gas-pressure cable, showing construction

metallised paper screen to form the dielectric, which is itself screened with copper tape. The lead-alloy sheath, extruded to a shrink fit over this core, is reinforced against the internal gas pressure by three layers of tin-coated bronze tape, all applied in the same direction. Between this tape and the jute yarn bedding for the armouring is a protective sheath of vulcanised rubber, capable of withstanding the highest lead sheath voltages liable to occur in service. The cable is armoured with a single layer of galvanised steel wire, applied in a direction opposite to that of the reinforcing tapes to balance torsional forces. The armour is served with two layers of compounded jute yarn and the cable has an overall diameter of approximately 4 in.

The possibility of damage occurring during or after installation made it necessary to have available a joint which could be used to effect a repair in the finished cable. Such a joint must be capable of withstanding the mechanical stresses exerted on it during re-laying, in addition to the continuous electrical and pneumatic stresses imposed upon it in service. The actual jointing operation must be capable of being performed in the shortest possible time owing to possible weather hazards at the time of jointing. Very considerable development work was carried out to evolve a satisfactory joint. Joints of the final design were given prolonged mechanical and electrical stability and submersion tests and were found to be entirely adequate. A number of these joints were manufactured and delivered to Vancouver in time for the cable-laying operations.

The contract required the cable system to be installed and in operation by the autumn of 1956. It was necessary that laying should take place in good weather and, as the laying would take about two months, the cable had to be on site in early summer. To meet these requirements, comprehensive plans and rigid time schedules were drawn up well in advance. The manufacture of the cable was completed in March 1956, several weeks ahead of schedule and the 91 miles of finished cable stored in the coiling-down shed, awaiting transfer to the cableship.

While the manufacture was proceeding, careful consideration was being given to plans for loading, transport and laying of the cables. All these operations were to be the responsiblity of the manufacturer. Very few cableships suitable for dealing with such a large volume and weight of power cable exist, but eventually one was chartered from Submarine Cables Ltd. This ship, the *Ocean Layer* of 4,600 tons —the second largest cableship in the world—was judged to be the most suitably equipped for the Vancouver undertaking.

The scheme finally decided upon by the British Columbia Electric Company was for alternating power at 60 cycles per sec. to be transformed from 230 kV to 138 kV at Arnott sub-station on the mainland and thence via an overhead route on wooden poles to a point at Tsawwassen Beach, just west of Point Roberts. From here, there is a submarine cable crossing across the Strait of Georgia to Galiano Island. An overhead line on steel towers then continues the transmission across Galiano Island, an intervening channel and Parker Island. A second submarine-cable carries the connection to a point on Saltspring Island and finally an overhead line across the island and another channel to Vancouver Island, where it is linked, at Stratford sub-station, with the Island's 132 kV system. In all, the length of line from Arnott to Stratford is approximately 48 miles.

In order to facilitate subsequent identification and, if necessary, recovery for repair, it was planned that the cables of the main crossing should have a spacing of approximately 500 yards and of the shorter crossing a spacing of 250 yards. In view of the probable future additions, the cable positions were planned on a basis of seven cables per crossing. This wide spacing for so many cables made it necessary for there to be considerable differences in length between cables for the same crossing, thus adding considerable complications to the planning and to the actual operation.

Immediately after each cable had been laid, a high-voltage d.c. test was carried out on the cable at atmospheric pressure. The cables were then moved into their final positions in the chases and the ends terminated in sealing ends. They were then gassed and the official high-voltage acceptance test carried out, together with other electrical tests and a pneumatic test to ensure gas tightness. To prevent damage to the cables, malleable iron protectors were fitted to the cable at the shore end of the concrete chases to below low-water mark at the three deep-water landings. At the Tsawwassen Beach landing, the protectors were fitted for a short distance from the tunnel entrance, the remainder of the shoreward end of the cable being buried in trenches.

All the cables were made alive in turn, the first trial transmission of power to Vancouver Island having taken place in late August, and the interconnection is now in full operation.

Klinger System of Handling Cement

An examination of the methods of cement transport now in use points to the fact that the economics of any large constructional undertaking demand bulk handling. On the Continent of Europe a high standard of efficiency has been developed, geographical considerations having a very large bearing on the matter. Because of the long haulage distances involved the railways have attacked the problem objectively and employ thousands of wagons with payload capacities in the vicinity of 30 tons and equipped for pneumatic discharge into site silos where sidings are available or into large bulking installations from which onward transit to site is undertaken by road vehicles similarly equipped. The Swiss Federal Railways first embarked upon the bulk transport of cement in 1949 with wagons built by Messrs. Cattaneo, of Guibiasco, using the "Pneutra-Klinger" system. In some instances, where no roads were available for onward transit from the bulking depot, transport by ropeway was introduced.

The French National Railways conducted an exhaustive enquiry into the existing methods of bulk cement transport by rail and road, and in 1955 embarked upon an initial programme of 300 wagons equipped with the Klinger system. The final programme envisages a pool of approximately 2,000 wagons, and a separate commercial organisation has been set up which now offers to cement manufacturers and users a chain of bulk transport from factory to site using both rail and road transport. In April 1957 construction will begin on a dam in the French Alps at Roselend, near Albertville, which will involve the transport of approximately 240,000 tons of cement, bulking being employed throughout. A large storage depot is being installed at Albertville station where 22 wagons can be discharged in half a day using equipment capable of pneumatically unloading four wagons at a time. Other railways which have standardised on the Klinger system are those of Germany, Italy, Austria and Finland. In considering the merits of any particular system the following desiderata are of importance:—

(a) High rate of discharge.
(b) Simplicity.
(c) Sound mechanical design.
(d) First-class construction.
(e) Ease of operation.
(f) Complete discharge of the containers.
(g) The ability to discharge over reasonable horizontal and vertical distances.

Messrs. Klinger A.G., of Wiesbaden, have made a particular study of this problem and the outcome of their researches is to be found in their axial-type conveyor jet which performs the dual function of aerating the cement and discharging it to the site silo, batching plant or stocking depot. The equipment, which has been manufactured on the Continent for the past seven or eight years, is capable of discharging ordinary and double cement at the rate of 1 to 1½ tons per minute and horizontally through pipes over distances of 300 ft. and 100 ft. respectively. The discharge of railway wagons can be effected in two ways; firstly, by direct discharge to silo, using a portable unit for the supply of the necessary compressed air at approximately 35 lb. per sq. in., and secondly, by discharging the contents directly into road vehicles which provide their own source of compressed air from a compressor driven either by a direct-coupled petrol engine or through a power take-off. The road vehicles, in most

cases, are equipped to discharge themselves, one man, the lorry driver, carrying out the entire operation with ease and with complete absence of dust. Loading of both road and rail vehicles is generally effected by gravity or, again, pneumatic loading can be provided. The illustration depicts a typical trailer unit with a single container of approximately 5 tons capacity, but chassis or trailers can be fitted with two or three such units, thus giving a maximum capacity of 15 tons. The containers are discharged separately. The Klinger equipment is now being manufactured in Great Britain by Dalzell Electric Welding Co. Ltd. (DEWCO), of Lanarkshire, Scotland; sales for the United Kingdom and Commonwealth are effected through a separate organisation, Dewco Sales Ltd., of Glasgow, C.2. Equipment for any suitable chassis or wagon underframe can be supplied.

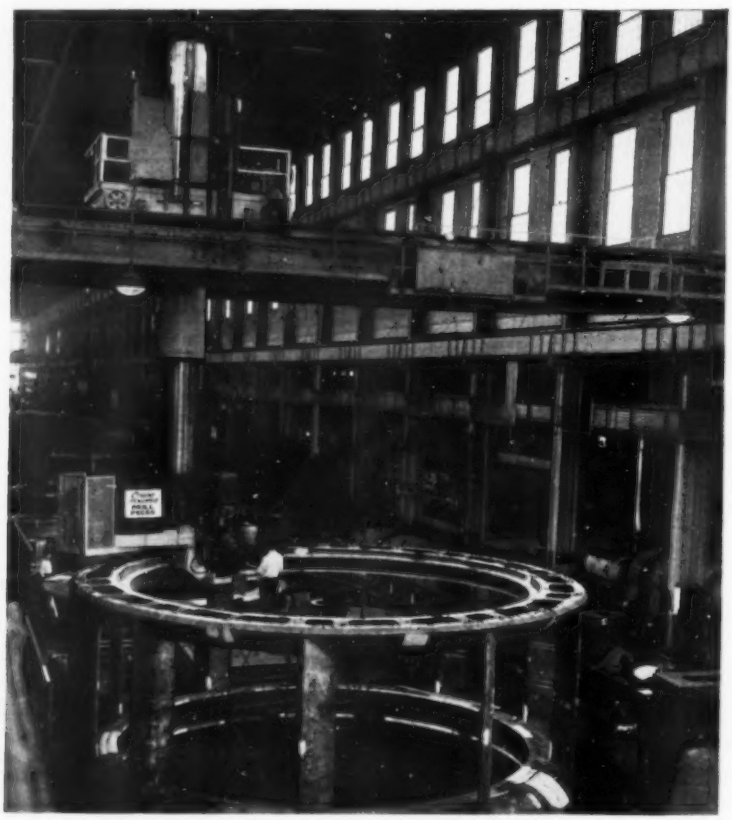
Returning to the question of the economics of bulk transport, it can be assumed that even if the price of bulk cement was equal to that of bagged, the employment of bulk transport would still show considerable savings. Direct economies can be itemised as:—

(a) The reduced cost per ton for bulk cement.
(b) The elimination of the cost of bags.
(c) 5 to 6% savings against losses due to torn bags, climatic variations, etc.
(d) The elimination of all labour for handling, the lorry driver only being involved.

Complete absence of dust is claimed and there are no moving parts other than the compressor.

Crane-Mounted Drill Press to Machine Stayring

Holes are being drilled in this 12-ft. high stayring for one of eight turbines for the St. Lawrence River power station at Barnhart Island near Messena, New York, by means of a crane-mounted radial drill press conceived by Allis-Chalmers, machine tool engineers. It is believed to be the first of its kind in size, range of travel and ease of control. The crane's radial drill head and arm supported from a carriage on the bridge of the overhead crane in Allis-Chalmers main erection building eliminates the need for setting large machines on blocks to drill, ream and tap holes in large workpieces such as this 31 ft. 10 in. diameter, 154,000 lb. stayring.



Each of the Allis-Chalmers fixed-blade propeller hydraulic turbines being built for the New York State Power Authority will deliver 79,000 h.p. at 94·7 r.p.m. under 81 ft. head. Propellers for these units will be 20 ft. in diameter—among the largest ever designed in the United States.

The dam and power house of the Barnhart Island project are scheduled for completion during 1958 and 1959.

Abstracts from the World Technical Press

Determining Turbine Efficiency by the Thermodynamic Method

This article describes the tests conducted at the Gondo power station in April 1955 for the purpose of determining the efficiency of water turbines by the thermometric method, now generally called thermodynamic. The tests represent the first application in Switzerland of this method, which was advocated as long ago as 1914 by M. Poirson, and more recently developed by the Technical Services of EDF. The method is based on the fact that losses of any kind occurring inside a turbine in operation are encountered as heat in the discharge water, so that the losses p can be expressed very simply by the formula

$$p = jcQ(\theta_s - \theta_e)$$

in which j is the mechanical equivalent of heat, c the specific heat of the water, θ_s water temperature at turbine outlet, θ_e water temperature at turbine inlet, and Q the turbine discharge. Once the losses are known, the efficiency of the turbine can be easily calculated by a formula such as

$$\eta = 1 - p/QH_n = \frac{1 - Jc(\theta_s - \theta_e)}{H_n}$$

H_n being the net head. Proceeding from this, the author works out formulae for calculating the turbine efficiency on the basis of the energy produced per time unit and output unit at the inlet and at the outlet cross-section of the turbine. The general procedure recommended for these measurements is then described. It is claimed that the technical means now available enable very good graphs to be plotted in the shortest time and at a minimum cost. From comparative tests made by EDF with thermodynamic measurements and measurements obtained by moulinets, the former appears the more reliable, both as to absolute efficiency and the scattering of measuring points. In his conclusion, the author is of opinion that the thermodynamic method may well prove best in the case of turbines working from medium and high heads. J. Chappuis, Vevey Engineering Works Limited, Vevey. *Bulletin Technique de la Suisse Romande*, Vol. 82, No. 11, May 26, 1956, p. 165, 6 pp., 5ff.)

Moving a Concrete Plant Bodily

This article describes how a 135 ton concrete batching and mixing plant, standing seven stories in height on a base of only 24 ft. square, was moved bodily more than two miles at Oahe dam near Pierre, S.D., where the world's largest rolled earth dam is being built across the Missouri River. The move transferred the plant from the upstream face of the dam, where it mixed 104,000 cu. yards of concrete lining for the upstream half of the six outlet works tunnels, to the downstream face, where it will prepare another 125,000 cu. yards for the downstream end of the tunnels and the control shafts, sunk in the axis of the dam. The only precaution taken to lower the centre of gravity was to empty the aggregate bins beforehand, and, helped by the total absence of wind on the day arranged for the move, the operation was carried out without the slightest hitch. Elevated on temporary blocking and bracing, and rolled on rubber-tyred dollies, the plant was hauled smoothly to its new location, 55 ft. higher than the old, with the help of a single diesel-engine truck, and boosted over one area of soft ground by a crawler tractor. *(Engineering News-Record*, Vol. 156, No. 25, June 21, 1956, pp. 49/50, 3 ff.)

Progress at Dalles Project

According to a recent report, concrete placement for the multi-purpose Dalles project on the Columbia River was 92 per cent. complete four years after construction began. These works include the dam, powerhouse, navigation locks and fishways. Range of completion varies from the 99 per cent. for the 23 gate spillway dam and stilling basin, to the fractional start of the rockfill closure dam to be completed in August 1957. Almost all phases of the project, apart from the generating equipment and the relocation of the highway and railroad, are either on or ahead of schedule. (*Electrical World*, Vol. 145, No. 23, June 4, 1956, p. 18, 1 f.)

Piping in Hydraulic Structures

This paper surveys briefly the influence of piping on the stability and security of hydraulic structures erected on permeable ground, and discusses the methods worked out on the basis of Terzaghi's investigations (Harza, Rao) for determining the extent of piping, as well as the methods advocated by Bazant, Herzog, Mandel, Marsland, and Baumgart in cooperation with the author. The model tests carried out in connection with these various methods are also reviewed. The results of these tests show that Baumgart-Davidenkoff's method is claimed to be the simplest and, especially in cohesionless soils (sand and the like), the safest. In the case of cohesive soils the critical height, as shown by Terzaghi's tests with loamy sands, can be much greater than in pure sand, and Harza's method should be applied, pending further research. (Dr. R. Davidenkoff, *Die Wasserwirtschaft*, Vol. 46, No. 9, June 1956, p. 230, 7 pp., 8 ff.)

Kemano-Kitimat Transmission Line Suspension

This paper, read at the 70th Annual General and Professional Meeting of the Engineering Institute of Canada, Montreal, May 1956, is devoted to the new type of cross-suspension system adopted for the permanent realignment of part of the Kemano-Kitimat transmission line which was destroyed by an avalanche in January 1955. After temporary repairs had been made, and the circuits established again, study was given to several schemes of permanent repair and a new alignment that would keep this section free from avalanche danger in the future. Considerations of safety, time and cost led to the use of the new type of cross-suspension. The work involved and the various components of the new system are described in detail. During the eight months it has now been in service, the system has behaved satisfactorily through a normally severe winter. (H. B. White, *The Engineering Journal*, Montreal, Vol. 39, No. 7, July 1956, p. 901, 12 pp., 14 ff.)

The Kaplan Turbine in Canada

The Chief Hydraulic Engineer of the S. Morgan Smith Company describes the physical arrangement and blade-operating mechanism of the Kaplan turbine, outlines the history of its development with emphasis on laboratory research, and briefly discusses its outstanding performance characteristics together with the attendant problems of cavitation, thrust, and runaway speed. The present use of Kaplan turbines for capacities up to 150,000 h.p. in the United States and heads up to 200 ft. in Europe indicates the broad field for potential application in Canada. This paper was read at the 70th Annual General and Professional Meeting of the Engineering Institute of Canada, Montreal, May 1956. (G. Dugan Johnson, *The Engineering Journal*, Vol. 39, No. 6, June 1956, p. 769, 11 pp., 7 ff.)

Pressure Surges in Turbines and Pumps

This article discusses the effects of pressure surges induced by turbines and pumps in pressure conduits. It deals first with water hammer in the pressure conduits of hydro-electric plants, and the admissible pressure drops in the horizontal section of the conduit connecting with the surge tank, as well as with the damage which may be caused to the pressure conduit by quick pressure fluctuations in the draft tube of Francis and propeller turbines. In the last two sections, the author examines the transient oscillations occurring in penstocks and originating in the runner outlet of the turbine, together with those produced in the delivery mains of pumping stations. (Dr.-Ing. H. Netsch, Kansas City, U.S.A., *Die Wasserwirtschaft*, Vol. 46, No. 5, February 1956, p. 114, 9 pp., 6 ff.)

Oster Dal Development, Sweden

To ensure the power supply to a new steel works, the great Stora Kopparbergs industrial concern is now constructing a large rockfill dam and power station at Trängslet, on the Oster Dal, about 50 km. downstream from the outlet of Lake Särna. The dam, 550 m. wide at its base, 120 m. maximum height and 850 m. in length, will create a reservoir of 1,200 million cu. m. capacity. Ancillary structures include two overflow spillways designed for a discharge of 1,000 cu. m. per sec., a bottom outlet with a tunnel to pass 100 cu. m. per sec., and a lumber pass to cope with 15,000 logs per hour; there is no fish ladder. The underground power station will operate under a head of 140 m., contributed to the extent of 115 m. by the river itself, the remaining 25 m. being provided by a tailrace tunnel 4·5 km. long, which cuts across the Trängsel Falls. The ultimate equipment will consist of three 75 MW generators driven by Francis turbines, of which two will be installed at the initial stage. From the intake, designed for a drawdown of 25 m., two 4·8 m. diameter penstocks, fitted with hyraulically controlled gates, will convey the water to the turbines; the 4·5 km. tailrace tunnel carrying the discharge back to the river is 110 sq. m. in cross section. Generation is scheduled to start with one set which will operate when the reservoir is only partly filled; this will be in the autumn of 1960 and the whole plant will be completed by the end of 1961. The reservoir, however, is not expected to be fully impounded until the following spring. The article describes the tunnelling work now in progress on the diversion and outlet tunnels, as well as on the access tunnel to the underground power house. These three tunnels, varying in cross section from 55 to 100 sq. m., are driven by the Swedish method by means of six Atlas-Copco BBD 41 hammer drills mounted on a two-tier jumbo. (*Travaux*, Vol. 40, No. 260, June 1956, pp. 363/364, 2 ff.)

Hydro-electric Prospects in China

A short survey is given of the potentialities of hydro-electric development in China. The specific conditions obtaining in the country confront the authorities with a fourfold task of a magnitude unknown elsewhere and concern (1) the control of the catastrophic floods which have been devastating the land and decimating the people for hundreds, not to say thousands of years; (2) the efficient irrigation of vast plains; (3) harnessing to hydro-electric development the enormous water resources of the country; (4) improving the navigability of the large rivers to increase transport facilities and the exchange of goods. Conditions are particularly favourable to cheap hydro-electric developments, numerous suitable sites being available in the vicinity of industrial regions. The assessment of harnessable water-power resources varies between 300,000 and 540,000 MW, the former figure involving 1,598 of the main watercourses and corresponding to about 70% of China's total potential. The latter figure was given at a recent national conference. Some 72% of these resources are concentrated in South-Eastern China and Tibet. From the surveys effected, it appears that the Yangtze-kiang basin alone has a power reserve of 22,000 MW, the corresponding figure for the Hwang-ho basin being 33,000 MW (23,000 MW, according to other estimates). Preliminary work is already in progress on two 1,000 MW projects—Sanmen and the Liuka Gorges, the production from which can be economically conveyed to neighbouring industrial centres. Favourable geological and topographic conditions will enable excavation and earth work for these two projects to be kept to a minimum, thus ensuring low construction costs and cheap energy. So far, China has resorted to the co-operation of East European specialists only, but the projects contemplated spread over such a long period that Western aid may also be called at a later stage. (J. Stieger, *Bulletin de l'Association Suisse des Electriciens*, Vol. 47, No. 12, June 9, 1956, p. 563.)

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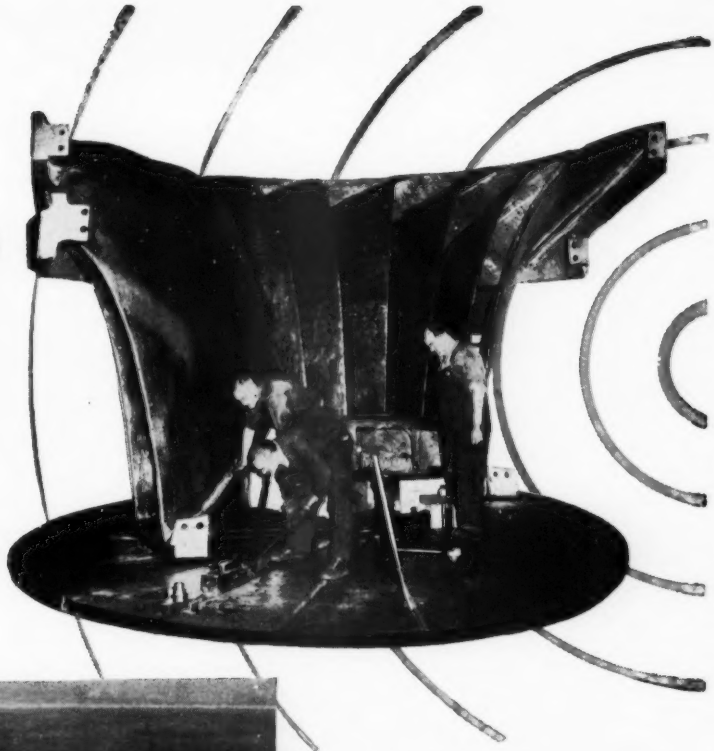

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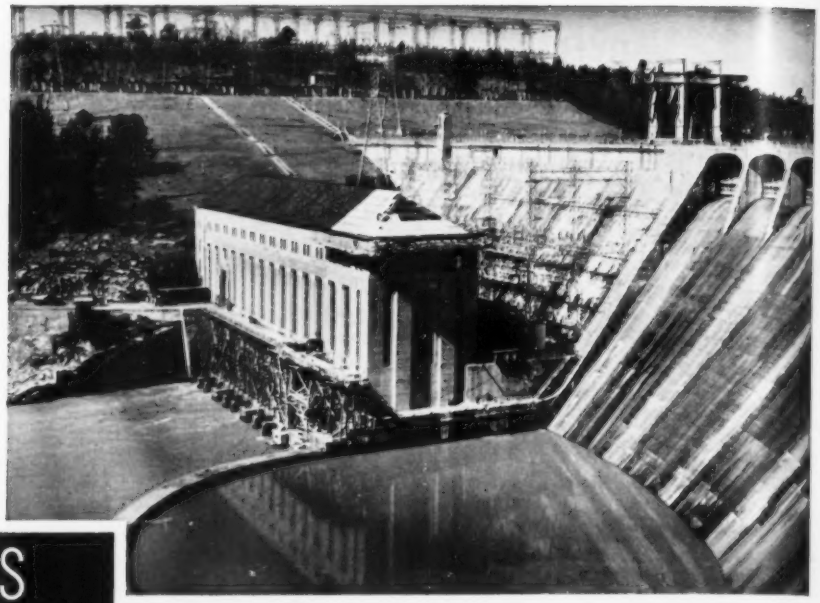

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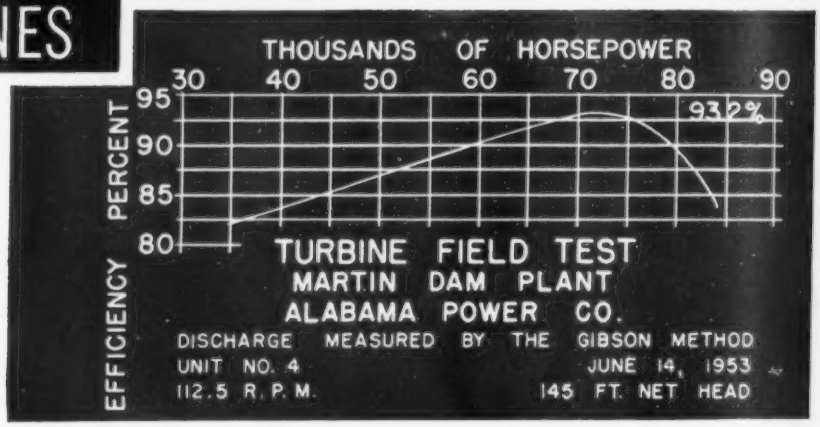

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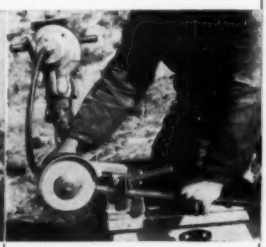

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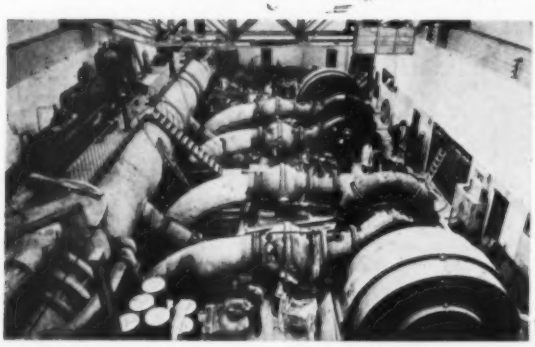

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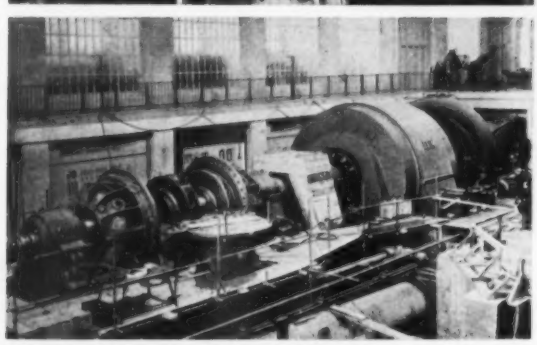

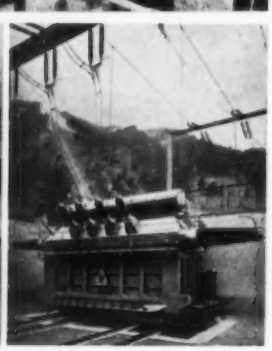

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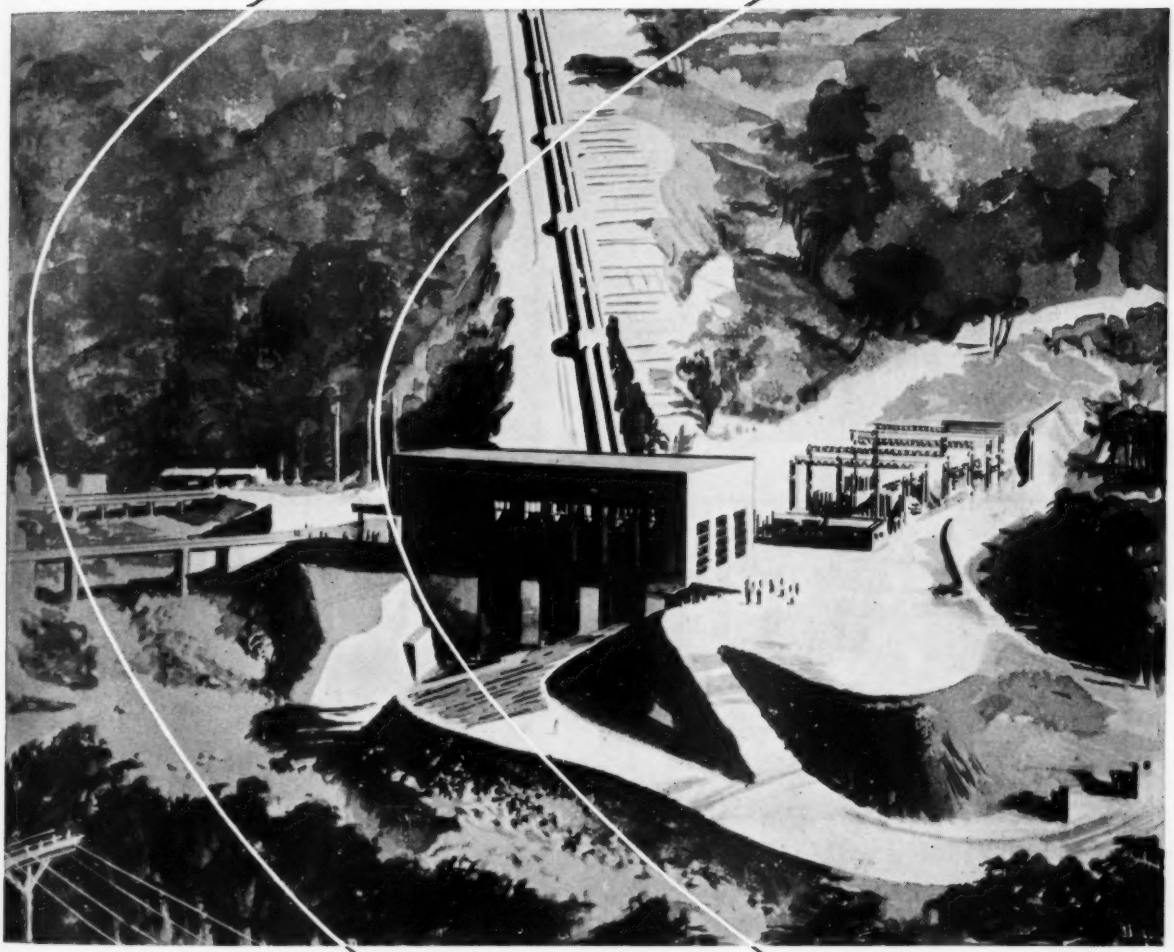

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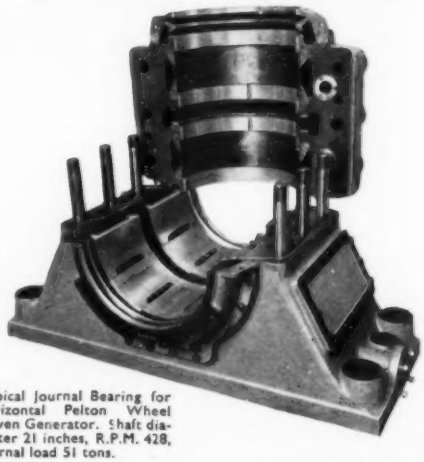

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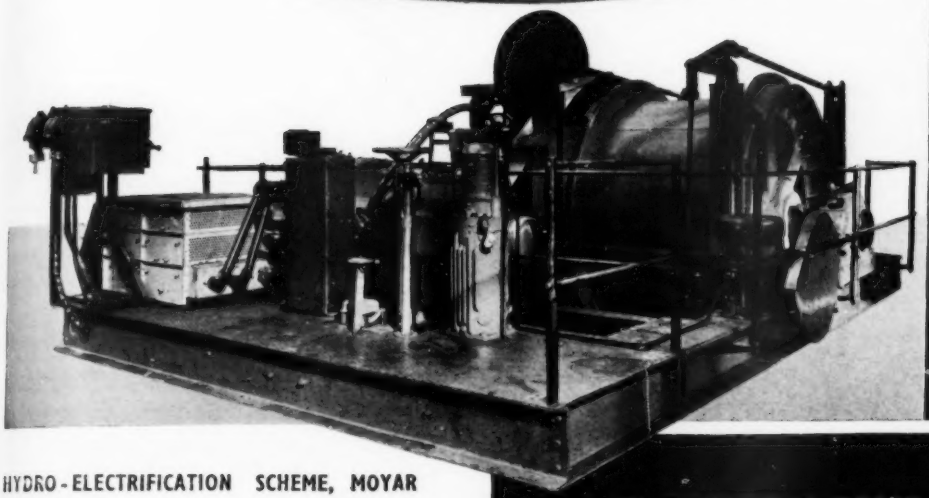

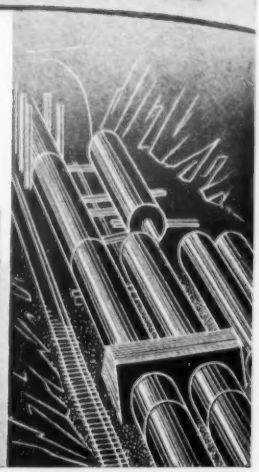

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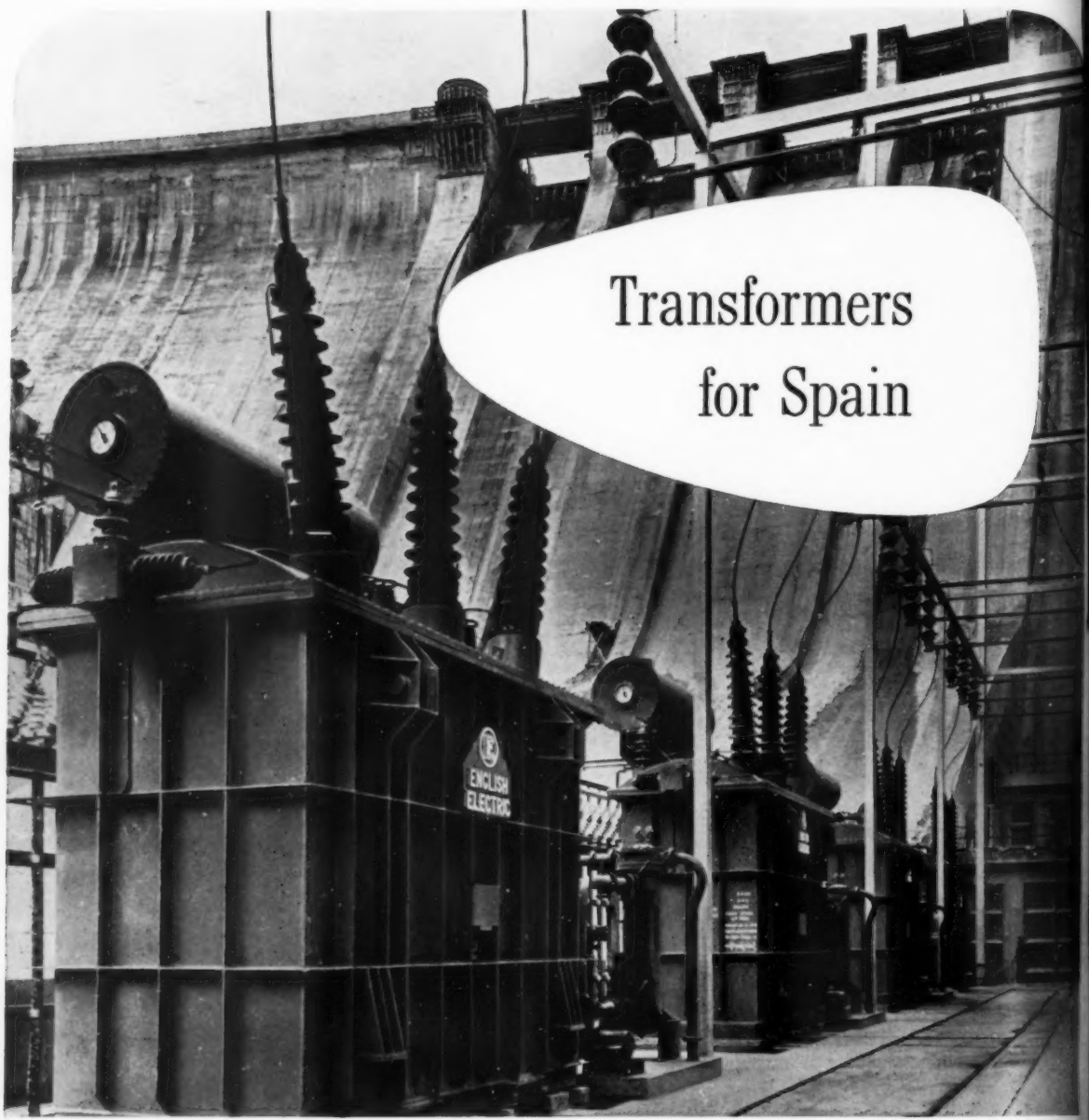

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